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EP-62

HANDBOOK OF
THE QUARTERMASTER RESEARCH & ENGINEERING
ENVIRONMENT AND CLIMATIC TEST FACILITI

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HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-62

HANDBOOK OF THE QUARTERMASTER RESEARCH & ENGINEERING CENTER ENVIRONMENT AND CLIMATIC TEST FACILITIES

Fernand P. de Percin
Geographer

Sigmund J. Falkowski
Meteorologist

REGIONAL ENVIRONMENTS RESEARCH BRANCH

Project Reference:
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FOREWORD

This report provides information on the environment and the environmental research facilities of the Quartermaster Research and Engineering Center, Natick, Massachusetts, and its surrounding area. To aid in the planning, timing, and evaluation of scientific studies and tests conducted at the Center, a description is given of the climate with its changing seasons, the ground and vegetation characteristics of the outdoor testing areas, the Climatic Research Laboratory, and other climatic test facilities. Where possible, information has been presented graphically to facilitate use.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection Research Division

Approved:

JAMES C. BRAIFORD, Colonel, QMC
Commanding Officer
QM R and E Center Laboratories

A. STUART HUNTER, Ph.D.
Scientific Director
QM Research & Engineering Command

CONTENTS

ABSTRACT

The Quartermaster Research and Engineering Center at Natick, Massachusetts, provides facilities for conducting research and development in many fields of science. Both indoor and outdoor climatic facilities for research and testing are available at the Center. These facilities include wind tunnels for simulating extreme climates and a solar furnace for testing materials designed to protect soldiers against thermal radiation.

A comprehensive weather recording and observing program is conducted at the Center by personnel of the Army Signal Corps. Topoclimatic stations are located in representative areas, and microclimatological measurements are made to determine the vertical distribution of weather elements as well as the physical processes involved.

The climate of the area is one of moderately cold, moist winters and warm, moist summers. January, the coldest month, has a mean temperature of 26.5°F, and minimum temperatures at or below freezing on an average of 29 days. July, the warmest month, has a mean temperature of 70.8°F and an average of 6 days with temperatures at or above 90°F. Mean annual precipitation totals 47.77 inches and is evenly distributed throughout the year. November, the wettest month, received an average of 4.76 inches, and October and July, the driest months, both have a mean of 3.36 inches. Snowfall may occur during all months from November through April, but significant amounts are likely only during December, January, February, and March.

The Natick area, like all of New England, was influenced by intensive glaciation, and the landforms in evidence today were caused chiefly by the last glacier to cover the region. Most lakes and ponds, including Lake Cochituate, owe their origin to glaciers. Soils of the area, derived from glacial material, tend to be acid and coarse.

Natick lies within the northeastern hardwood forest. Trees, which are all second or later growth, include American elm, gray birch, red maple, several species of oak, and some white pine. Marshy areas consist mainly of sedges, cat-tail, and small willows.

HANDBOOK OF
THE QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENT AND CLIMATIC TEST FACILITIES

1. Introduction

The Quartermaster Corps has been responsible for providing food, clothing, equipment, and other needs of the United States Army since 1776. The problems of developing these items are manifold, and for years have been investigated at laboratories at various places throughout the country. The Quartermaster Research and Development Center* was established in 1953 to consolidate Quartermaster research and development activities. The Center provides facilities in which the efforts of scientists and technologists in many fields of science and industry can be coordinated for developing and improving the many thousands of items for which the Quartermaster Corps has responsibility. For example, between 1947 and 1954 the Quartermaster Corps introduced nearly 500 new line items or materials into supply, and, in addition, during this period more than 800 standard items of issue were modified to improve functional characteristics (Calloway, 1954).

The Quartermaster Research and Engineering Center is in the town of Natick, Massachusetts, at 42° 17' N. latitude and 71° 22' W. longitude (Fig. 1), on a peninsula on the east side of Lake Cochituate.

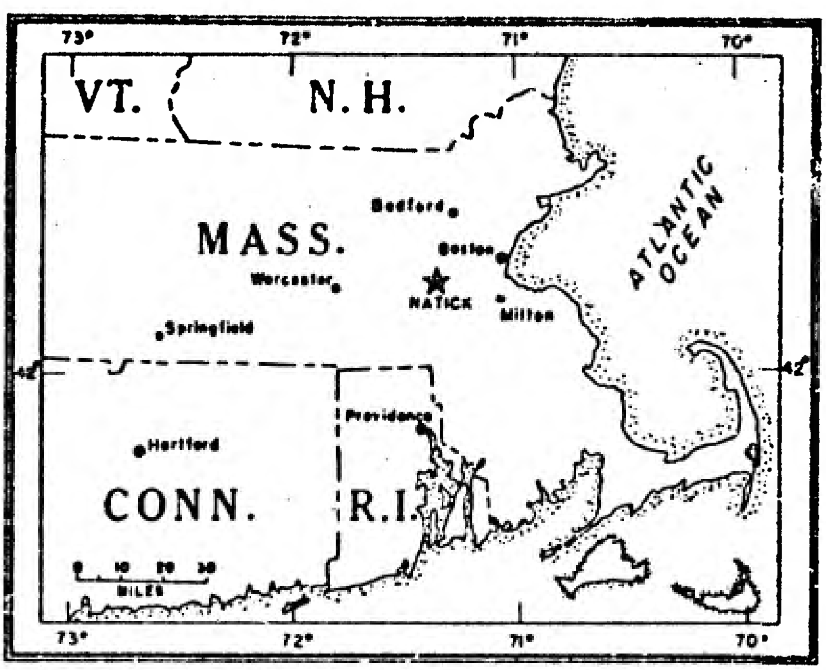

Figure 1: Location of Natick, Massachusetts.

*Redesignated Quartermaster Research and Engineering Center QMC Circular 57, 7 May 1957

The Center is approximately 20 miles west of the center of Boston and 5 miles east of the town of Framingham. Natick is accessible from all points by major highways and by the Boston and Albany Railroad. Framingham is the nearest station stop for through trains. The nearest commercial airport is Logan Field, the municipal airport for Boston, 23 miles from the Center. The nearest military airport is Hanscom Air Force Base, near Bedford, Massachusetts, 17 miles from the Center.

Laboratories in the buildings shown on Figure 50 (following Appendix) are used for conducting research and development in chemicals and plastics, environmental protection, mechanical engineering, pioneering research, and textiles, clothing, and footwear.*

2. Climatic Test Facilities

Both indoor and outdoor facilities are available for testing items during their development. Location of buildings and test areas is shown on Figure 50.

a. Climatic Research Laborator

Among the more important facilities are the wind tunnels in the Climatic Research Laboratory. A floor plan of this building is shown in Figure 2. The wind tunnels simulate conditions that occur in various environments. They were designed, and are used primarily, to determine physiological and psychological reactions of troops under controlled conditions, but they may also be used to test items of equipment. Scientists conducting tests in the wind tunnels can observe and direct - from an observation room - the activities of test subjects and record their reactions (Figure 3). A two-way communications system is provided between the tunnels and observation room. The Arctic and Tropic wind tunnels are discussed in greater detail below.

(1) The Arctic Wind Tunnel (Figure 4) occupies a total area of 900 square feet (60 ft. by 15 ft.), with height ranging from 8 ft. 8 in. at the sides to 11 ft. 3 in. at the center, and includes two treadmills (each 4.5 ft. by 8 ft.) that may be adjusted from a level position to a 12 percent grade. These treadmills are designed to carry 4 fully equipped men at speeds adjustable from 1.5 to 15 mph ($\pm$ 0.1 mph).

This wind tunnel is designed to provide and maintain dry-bulb temperatures within the limits -70°F to 70°F ($\pm$ 1F°). With dry-bulb

*Quartermaster research on food processing and packaging is conducted by the Quartermaster Food and Container Institute for the Armed Forces, Chicago, Ill. Field tests of newly developed Quartermaster items are conducted by the Field Evaluation Agency, Fort Lee, Virginia. These two installations, with Quartermaster Radiation Planning Agency, Washington, D. C., and the Center at Natick, comprise the Quartermaster Research and Engineering Command.

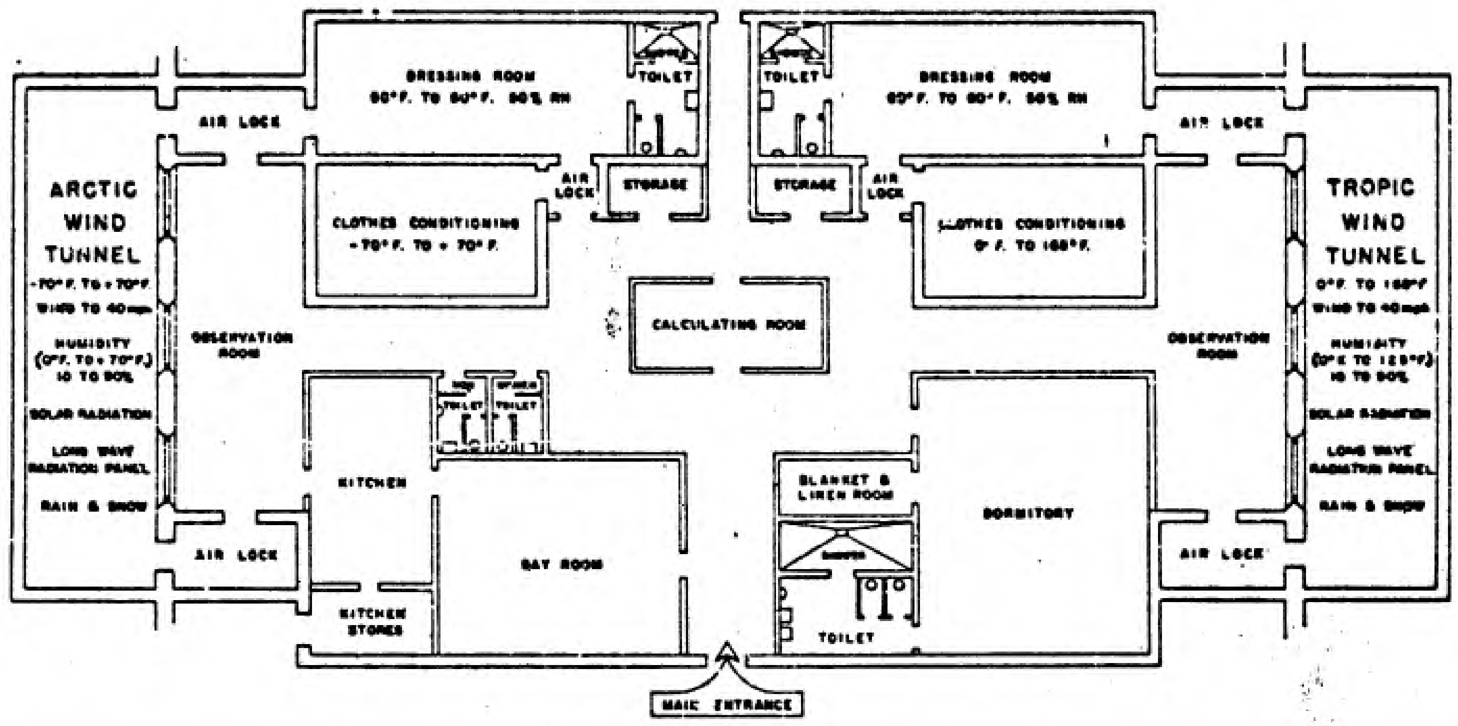

Figure 2: Climatic Research Laboratory floor plan.

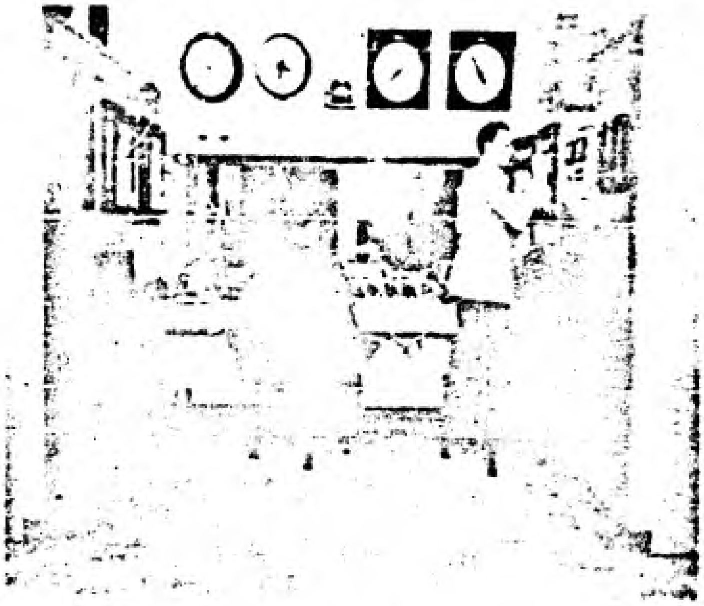

Figure 3: Instrument and observation area used by scientists conducting studies in the Arctic Wind Tunnel.

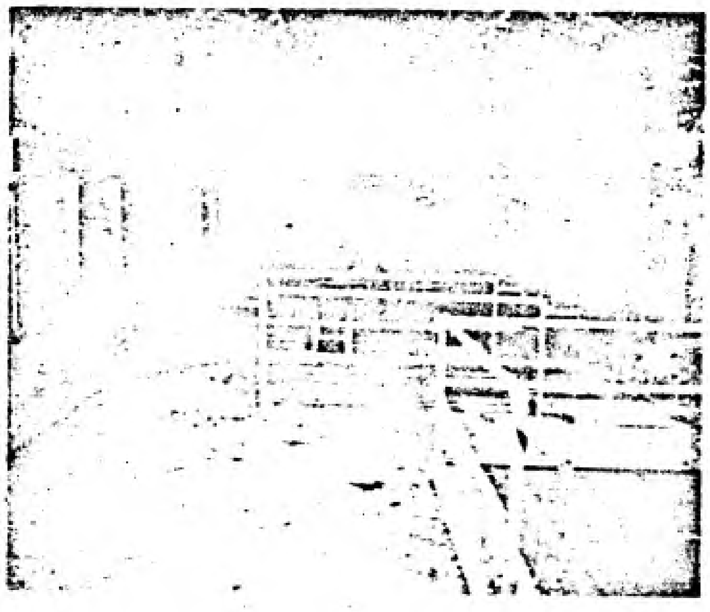

Figure 4: Interior of Arctic Wind Tunnel with study in progress. Wires lead to thermocouples which are attached to skin of test subjects.

temperatures $0^{o}F$ to $70^{o}F$ the chamber is designed to maintain dewpoint temperature from $-40^{o}F$ to $67.5^{o}F$ within a $1F^{o}$ limit, giving relative humidities from 10% to 90%. There is no control of humidity at dry-bulb temperatures ranging from $0^{o}F$ to $-70^{o}F$. Wind speed can be controlled within limits as follows:

Windspeed at (mph)	Temperature (^{o}F)
2 to 5	-70
2 to 10	-60
2 to 28	-50
2 to 40	-40 to 70

The area to be used for simulating rainfall is 15 by 20 feet. Up to 4 inches of rainfall per hour will be produced, and snow-making and distributing equipment will be provided to operate when ambient air temperatures in the wind tunnel are below $32^{o}F$. Estimated completion dates are winter 1957-58 for the rain facility and 1959-60 for snow-making equipment.

In the Arctic dressing room (15 by 35 ft.) (Fig. 5), temperatures can be maintained at any temperature between $60^{o}F$ and $80^{o}F$, with a relative humidity of 50%. In the Arctic clothing conditioning room (15 by 26 ft.), temperatures can be maintained at any point between $-70^{o}F$ and $70^{o}F$.

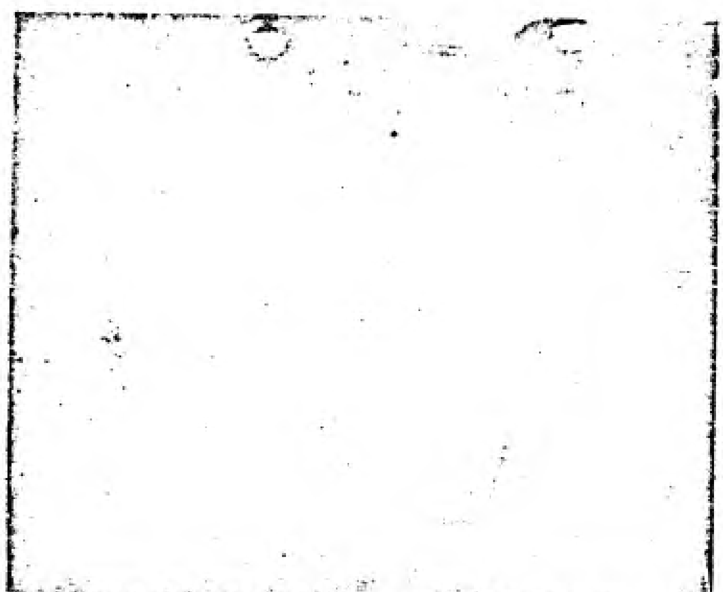

Figure 5: Arctic dressing room showing test subjects engaged in study.

Low temperature radiation panels which can be heated or cooled will be provided in the Arctic Wind Tunnel during 1957 or 1958. These panels will be mounted on the ceiling and sides for a length of 20 feet, and will be movable and demountable. In addition, ultraviolet and infrared radiation will be provided in a section of this wind tunnel.

(2) The Tropic Wind Tunnel is designed to maintain temperatures from 0°F to 165°F (±1F°). For temperatures from 125°F to 165°F there is no control of humidity. With dry-bulb temperatures from 0°F to 125°F, however, the tunnel is designed to provide dewpoint temperatures from -40°F to 120°F (± 1F°), which give relative humidities from 10% to 90%. Windspeeds can be controlled within limits as follows:

Windspeed at (mph)	Temperature (°F)
2 to 5	140 to 165
2 to 20	130
2 to 30	120
2 to 40	0 to 110

The facilities of the Tropic Wind Tunnel are similar to those of the Arctic Wind Tunnel. Treadmills are of the same dimensions and capabilities, and rain, snow, and radiation will also be produced in the same way as in the Arctic Wind Tunnel. The tropical clothing conditioning room is designed to maintain room temperatures between 0°F and 165°F, but there is no control of humidity. The tropical dressing room temperatures can be maintained between 60°F and 80°F at 50% relative humidity.

b. Solar Furnace

Construction of a large solar furnace was begun in February 1957, at a location west of the boiler house on the shore of Lake Cochituate, and will be completed in 1958. It is to be the largest solar furnace in the United States, and will be used to test material designed to protect soldiers against thermal radiation. Reliance upon atomic tests in field trials will be necessary only for final evaluation.

The installation, which is over 100 feet long, will use simple optical principles to achieve a concentration of solar radiation. The direct radiation from the sun is reflected from a large array of flat mirrors, the heliostat, to another array of concave mirrors, the concentrator. The concentrator produces a convergent beam which is focused on a target position. An image (about 4 inches) in diameter) of the sun is formed. A water-cooled protective shutter and a fast-acting exposure shutter control the projection of this image

on samples placed at the target position. An automatic positioning system drives the heliostat to keep it at the correct angle with the sun. The directly reflected rays illuminate the concentrator during daylight hours, regardless of the time of day or year. It is hoped that irradiances greater than 60 calories/cm^2/sec can be obtained frequently in research studies on thermal protection.

c. <u>Raintower</u>

Simulated rain can be produced not only in the climatic wind tunnels but also in the Engineering Building, which contains a 40-foot raintower capable of producing a maximum rainfall of 8 to 9 inches per hour. The height of the tower allows drops to reach terminal velocity similar to that attained by raindrops in nature.

d. <u>Outdoor Test Areas</u>

Facilities are also available to a limited extent at the Center for conducting outdoor tests. Outdoor test areas include the gravel pit and Point area (Figure 50). These areas can be used for studying the effect of exposure on materials, for conducting development tests on mechanical equipment and clothing, and for physiological measurements.

The gravel pit (Fig. 6) has a level surface, part of which (about 25%) is surfaced with asphalt. Power (110 volt, 60 cycle, single-phase, and 220 volt, single cycle, three-phase,, telephone connection, and water supply are available at the pit.

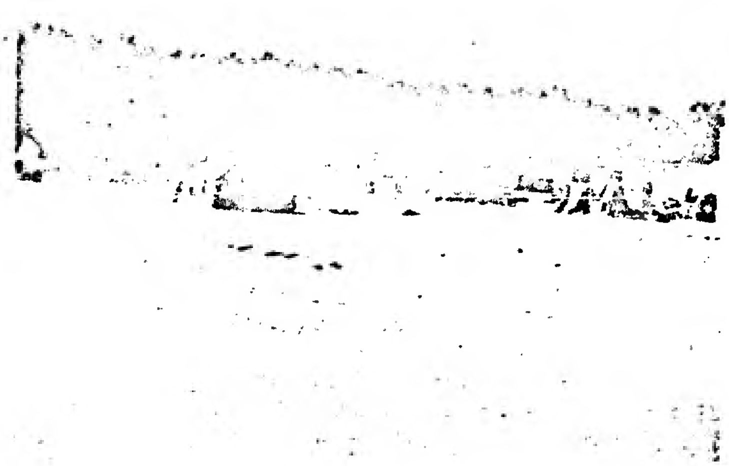

Figure 6: Gravel pit, view facing northwest.

The Point area (Fig. 7) is provided with power (110 volt, 60 cycle, single-phase, and 220 volt, single cycle, three-phase), telephone connections, water supply, and a fuel dump for storing fuel required during certain tests.

Figure 7: Point area showing test in progress

On the west side of the peninsula, some 60 feet of shore has been cleared. A 40-foot pier, which may be used during immersion tests of items, extends from this cleared strip into the lake (Fig. 8). The water at the end of the pier is only 3 to 4 feet deep, but a large part of the lake, several hundred feet from the pier, is 60 feet deep (Dept. of Natural Resources, Comm. of Mass., 1952).

e. Meteorological Stations and Observations

A comprehensive weather recording and observing program is in operation at the Center. The observations and measurements provide meteorological and climatological data required by research scientists and test planners in all Divisions at the Center. Weather conditions influencing tests and studies are recorded in detail.

A primary weather station is located on the lawn near the south end of the Administration Building (Fig. 9). This station is equipped with a standard instrument shelter, containing a hygrothermograph, maximum and minimum thermometers, psychrometer, and the sensing element of a Foxboro dewcell. A standard 8-inch rain gauge, a recording weighing rain gauge, net exchange radiometer, and a soil-heat transfer plate are also installed at this station (Fig. 10). Wind recording

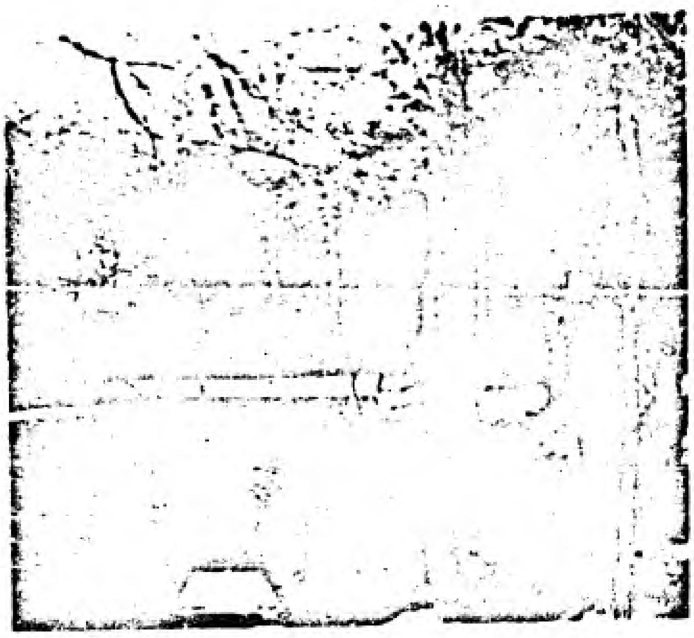

Figure 8: Pier used in immersion tests, on west side of peninsula.

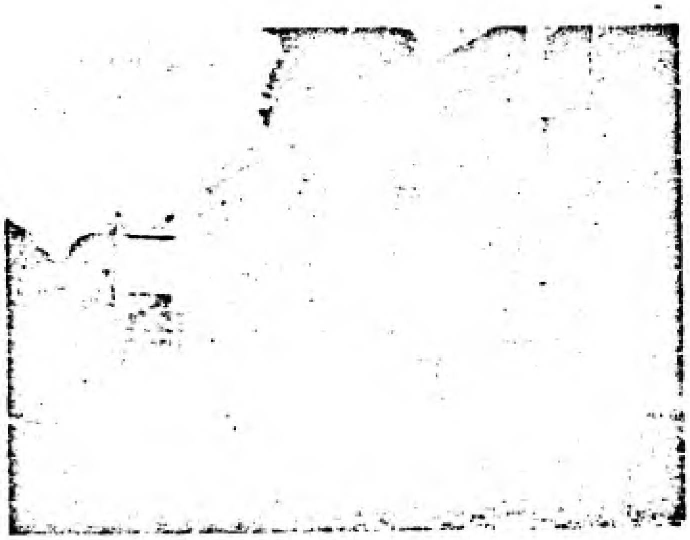

Figure 9: Primary weather station, showing rain gauge, net exchange radiometer, and instrument shelter.

instruments, a recording tipping-bucket rain gauge, an Eppley pyrheliometer (for measuring solar radiation), and a total hemispheric radiometer are mounted on the roof of the Research Building (Fig. 11).

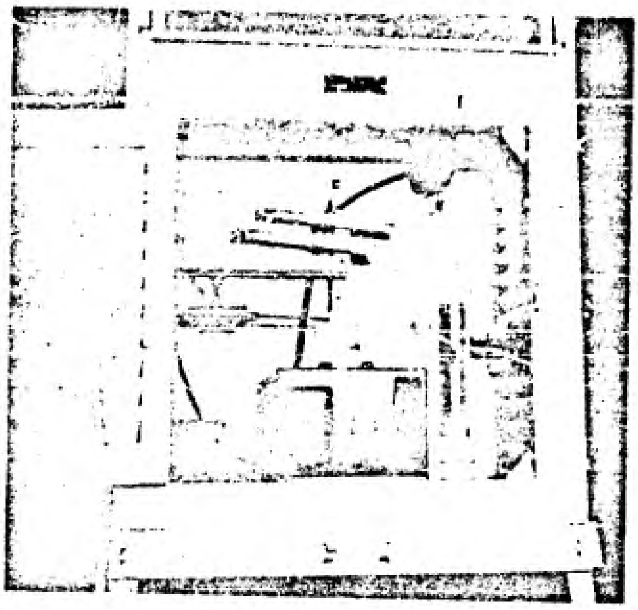

Figure 10: Interior of instrument shelter at primary weather station showing arrangement of instruments

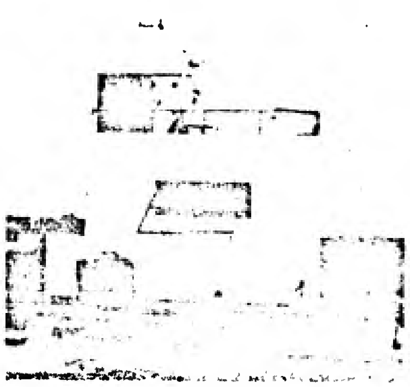

Figure 11: Roof of Research Building, showing meteorological instruments.

Recorders for electrical instruments are located in the Research Building and the Administration Building. Visual observations include visibility; time of beginning and ending, and type of precipitation; amount, type, height, direction of movement, and speed of clouds; ground conditions; and snow cover and depth.

Additional weather stations have been installed in the Point area (Fig. 12), in the gravel pit (Fig. 13), in the wooded area south of the Climatic Research Laboratory (Fig. 14), and on the bluff on the west side of the peninsula (Fig. 15). Each station is equipped with a rain gauge and an instrument shelter containing a thermograph and maximum and minimum thermometers.

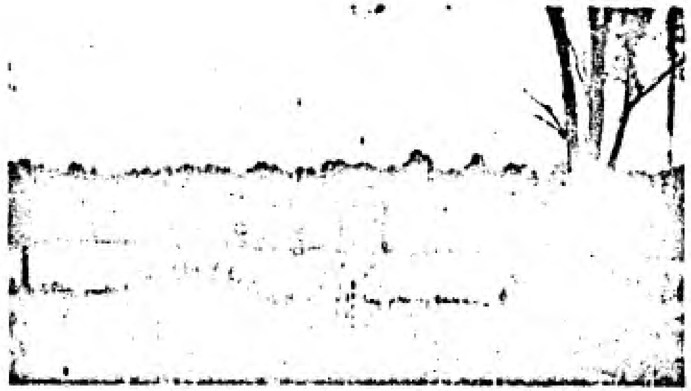

Figure 12: Topoclimatic Station, Point area.

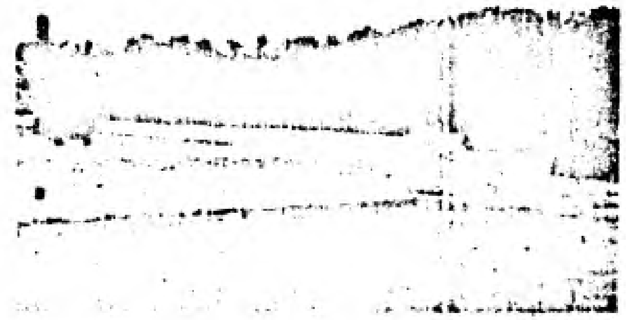

Figure 13: Topoclimatic Station, gravel pit.

Figure 14: Topoclimatic Station, woods south of Climatic Research Laboratory.

Figure 15: Topoclimatic Station, bluff on west side of peninsula.

Locations of these topoclimatic stations are shown on Figure 50.

3. Climate

New England, lying in the middle latitudes, comes under the influence of frequent conflicts between cold, dry air masses flowing out of the great subpolar region to the northwest and the warmer moisture-bearing, tropical maritime air masses from the south (Nesmith, 1941). The Natick area has m erately cold, moist winters and warm, moist summers. Occasional oce ic influences reach the area and reduce the frequency of extreme high or low temperatures. Precipitation is moderately abundant in all seasons of the year, although considerable variation in amount and distribution may occur from year to year. Winter precipitation is generally in the form of snow. Once or twice a year, storms with freezing rain (glaze) occur, forming ice accumulations on exposed surfaces and causing widespread damage (Bennett, 1957).

The area is subject to storms in both summer and winter, due to the frequent passage of frontal systems. Frontal and convectional thunderstorms, with gusty winds, are frequent in summer. Adverse weather conditions of longest duration experienced in summer usually are due to warm fronts or stationary fronts to the south. These frontal systems cause extended periods of cloudiness, drizzle, and low visibility in the area. Cold front weather in winter is usually more severe than that which occurs in summer. There is usually continuous snow ahead of the cold front, lasting up to two hours after the frontal passage, after which time there is a general improvement in the weather conditions. In winter, warm fronts which form in, or pass by, the vicinity of Long Island, New York, cause precipitation in the form of rain or freezing rain in the Natick area.

In late summer or early fall (August and September) the weather is sometimes influenced by hurricanes. Most of these storms do not pass directly over the area, but at times cause considerable precipitation and strong winds. The area has been affected by hurricanes about 17 times in the past 55 years, but not more than 7 of these storms were severe enough to cause extensive damage.

Climatic data are presented in detail in the graphs and tables in the Appendix, and discussed below.

a. Data Sources

Few weather observations have been taken in Natick proper, and climatic information used in this study is based on records obtained from weather stations located between 3 and 15 miles from the Laboratory site.

Temperature values were computed from data obtained from 25 years of weather records at the Lake Cochituate observing station, maintained by the Metropolitan District Commission (Water Division, 1954). Twenty-seven years of records from this station were used in determining

the precipitation regime. The Lake Cochituate station is located on Route 30 on the west shore of Lake Cochituate, approximately 3 miles north of the Center, at 148 feet above mean sea level.

Radiation and sunshine data cited are from observations at the Harvard Blue Hill Meteorological Observatory (elevation 640 ft.) in Milton, Massachusetts, about 14 miles east-southeast of Natick (U. S. Weather Bureau, 1953). Mean monthly radiation data are for a 7-to 9-year period, but mean weekly values are presented for a period of 15 years (Hand, 1949). Sunshine data are for a 69-year period. Comparison of the data from Blue Hill with nearby areas indicates no significant differences in the radiation and sunshine received, and it may be assumed that the data are also representative of Natick.

Data for wind, snow depth, visibility, sky condition, and ceiling height were obtained from the U. S. Air Force weather station at Hanscom Air Force Base (elevation 135 ft.) at Bedford, Massachusetts, 17 miles north of the Center (USAF, 1954). These data were obtained for periods of record varying from 5 to 11 years. Owing to differences in topography, vegetation, and land-water relationships at the two sites, some differences must be inferred between conditions observed at Bedford and those occurring during comparable periods at Natick, particularly with respect to visibility, and wind speed and direction frequencies. Such differences presumably would be small with regard to visibility but significant with regard to wind direction at lower values of wind speed.

b. Temperature

Mean temperatures (Fig. 18 and Table I) in the Natick area are moderately high in summer. July, the warmest month, has a mean temperature of 70.8° and mean daily maximum and minimum temperatures of 83.7°F and 57.9°F, respectively, for the period 1929 to 1953. The highest temperature recorded in July was 101°F. The absolute maximum temperature observed during the entire period of record was 103°F, recorded in September 1953. The absolute minimum temperature for July is 39°F.

Temperatures at or above 90°F may be expected about 3 days in June, 5 days in July, 4 in August, and 1 day each in May and September (Figs. 23 through 27). Temperatures at or above 80° normally occur about 16 days in June, 24 days in July, and 20 days in August.

January is the coldest month. For the Lake Cochituate weather station, the mean January temperature for the period 1929 to 1953 is 26.5°F, and the mean daily minimum temperature, 15.0°F. The absolute minimum temperature of -28°F has been recorded in both January and February, but not in the same year. The mean daily maximum temperature in January is 38.1°F, and the absolute maximum, 70°F.

Temperatures at or below freezing (32°F) may be expected on more than 25 days each month from December through March (Figs. 19,

20, 21, and 30). Temperatures at or below 0°F normally occur on less than 1 day in November, 2 days in December, 4 days each in January and February, and 1 day in March.

Table I, Appendix, lists the standard deviations from the mean, mean daily maximum, and mean daily minimum temperatures. The values presented indicate the variability of temperatures in the area. As is evident from the figures, the warmer months of the year have the least variability. This is especially true of September, which has standard deviations of only 1.8F°, 1.6F°, and 2.3F° for the mean daily maximum, mean, and mean daily minimum temperatures, respectively. January, the month of greatest variability, has standard deviations of more than 5F° for the mean daily maximum, mean, and mean daily minimum temperatures. In other words, monthly temperatures in January can be expected to be more than 5F° above or below the mean in 2 out of 3 years.

c. Precipitation

The mean annual precipitation at the Lake Cochituate station is 47.77 inches. On the average, precipitation is evenly distributed throughout the year (Fig. 31 and Table II). The mean precipitation for July and October, the driest months, is 3.36 inches; and for March and November, the wettest months, 4.68 and 4.76 inches, respectively. In summer, precipitation is generally associated with convective activity. It usually occurs in thunderstorms, and is of short duration but relatively high intensity. Winter precipitation is usually of low intensity, but lasts for periods of one to several days, and is most commonly associated with the passage of slowly moving low pressure systems.

The maximum amount of precipitation received in one month at Lake Cochituate station was 15.35 inches recorded in August; the minimum amount, 0.44 inch, occurred in October. The greatest amount in 24 hours, 6.90 inches, was recorded in September 1954, during a hurricane.

Snowfall has been recorded in all months from November through April, but significant amounts may be expected only during December, January, February, and March; these months have average values of 8.2, 13.7, 13.8, and 6.8 inches, respectively (Fig. 32 and Tables III and IV). The greatest amount recorded in one month, 46.1 inches, occurred in March 1956.

The frequency of precipitation amounts (rain and water equivalent of snow) is shown in Figures 33 through 44. In January, about 7 days may be expected to have 0.10 inch or more, and 3 days 0.50 inch or more. In July, 0.10 inch or more may be expected on 6 days of the month, and 1.00 inch or more on 1 day.

Monthly precipitation, and especially snowfall, varies considerably from year to year. In January, which has a mean precipitation of 4.13 inches and a mean snowfall of 13.7 inches, the standard deviations are 1.72 and 10.2 inches, respectively. Values for other months are shown in Table IV.

d. Wind

Winds are usually light to moderate through the year in the Natick area. At Hanscom Air Force Base, winds of 25 mph or greater are most frequent from November through April, with the maximum occurrence of about 5% in February (Fig. 45, and Tables V, VI, and VII). Calm conditions prevail an average of 27% of the time in August, which has the greatest amount of calm weather, and an average of about 13% of the time in March, the month with least frequent calm conditions. Wind speeds of 75 mph or greater are experienced very infrequently; they are usually associated with the passage of a hurricane.

e. Cloudiness

Late spring and early summer (May, June, and July) have the greatest amount of cloudy weather. At Hanscom Air Force Base, during these months, approximately 83%, 85%, and 83% of the days, respectively, have some cloud cover (Fig. 46 and Table VIII). Low overcast sky conditions are least frequent during the period from June through October, when only 17% to 24% of the days have this sky cover. From August through April, approximately one-quarter to one-third of the days are clear.

Ceilings above 9,500 feet occur more than 50% of the time in all months, but are most frequent in summer (July, 71.7%). January, with 14.4%, has the greatest number of days with ceilings 900 feet or less. July, with 7.9%, has the least number of days with ceilings of 900 feet or less (Table IX).

f. Sunshine and Radiation

The hours of possible daily sunshine vary during the year from a minimum of about 9 hours in December to a maximum of 15½ hours in June. The amount of sunshine actually received in each month is only about one-half the hours possible (Fig. 47).

Radiation varies from a minimum daily average of 125 and 135 langleys, respectively, during December and January, to maximum values between 530 and 540 langleys during June and July (Fig. 48). The greatest weekly mean values of daily total solar and sky radiation occur from about the middle of June to the middle of July (Fig. 49).

g. Visibility

Visibility in the Natick area is good. Visibilities of 10 miles or more, as recorded at Hanscom Air Force Base, normally occur 43.0% of the time in August, the month with most frequent restricted visibilities, and 63.3% of the time in April, the month with the best visibility conditions (Table VIII). The chief restrictions to visibility are fog and precipitation. Visibilities of one mile or less are least frequent in April and June (average occurrence, 2.9% and 3.0% of the time, respectively).

h. Humidity

Humidity data (Table X), obtained from the records of the Signal Corps Meteorological Team at the Center, are for a period of only one year. Data for a longer period were available only from a source distant from the Center, and are not included in the study, since it was expected that the Center, bordered on three sides by water, might have higher humidities than Hanscom Air Force Base or Blue Hill Observatory.

Mean monthly maximum relative humidities are above 75% during all months. Due to the differences of the hours of observations (February through September observations were taken only from 0730 hours to 1930 hours; October through January observations were taken 24 hours each day), it is not possible to determine accurately the months having highest relative humidities. During summer especially, when observations did not begin until 0730 hours, it is likely that maximum relative humidities occurred too early in the morning to have been recorded.

Minimum relative humidities usually occur in the early afternoon, and mean monthly minimums varied from a low value of 40.0% in May to a high value of 57.9% in December.

Additional data, covering a longer period, are required before reliable information concerning the annual regime of relative humidity can be provided. It is intended that a supplement to this report will be issued when sufficient humidity and other climatic data have been compiled at the weather station at the Center.

4. Topography

a. General

The Natick area lies within the Seaboard Lowland of the New England Province as defined by Fenneman (1938). Although New England was glaciated several times, the landforms evidenced today were caused by the last glacier to cover the region (an estimated 10,000 years ago), which also destroyed most evidences of earlier glaciation.

The surface character of the New England Province is described as follows by Wright (1934):

> "Much of New England is a country of ancient, worn-down mountains, a land of extremely complex rock structure. The ceaseless forces of erosion have etched out a pattern of valleys below the general levels to which the mountains were reduced far back in geological times, and the complexity of relief reflects the complexity of the underlying rocks. The invasions and retreats

of the continental ice sheets did much to accentuate the diversified quality of the surface. The ice scraped the earth and carried away pieces of rock from countless hillsides; it dropped its load in moraines, damming streams and impounding the waters in lakes and ponds. It turned rivers aside from their older channels. It scattered boulders and gravel far and wide. Its melting waters gathered along the ice fronts in lakes, now vanished. On the floors of these lakes, sand and mud were laid down, and these deposits today form little plains, often terraced by post-glacial streams."

The Natick area strongly reflects this influence of glacial activity. All conspicuous landforms in the area are either directly or indirectly the result of glaciers or their associated meltwaters, and subsequent action of the forces of erosion and weathering. Ground moraine, or glacial till, forms a stony mantle over the bedrock in much of the region, and outwash plains are common. Stones of all sizes make agriculture difficult, and account for one of New England's traditional landmarks - the stone fence. Glacial erratics brought from a distance are common, but for every one of these there are thousands of stones derived from the local bedrock.

The effects of glaciers in altering relief, reflected in the drumlins, eskers, knobs and kettles, kames and terraces of various types, have probably been less than their influence on drainage. Most lakes and ponds, including Lake Cochituate, owe their origin to glaciers. Many have become swamps or meadows. Others have been modified by man through drainage or damming. Stream patterns and drainage are complex because they have been entirely reformed. Deposition by glaciers forced streams to find new channels, and often no trace can be found of old channels.

b. Quartermaster R&E Center

The Quartermaster Research and Engineering Center is located on a pitted outwash plain which forms a peninsula extending into Lake Cochituate. This plain, which has an average elevation of 165 feet above mean sea level, and about 30 feet above the lake surface, is believed to be composed in large part of stratified drift, a mixture of sand and gravel deposited by running water. Pits, or kettles, were formed when ice remnants, buried or partly buried in the drift, melted, and slumping took place. Much of the site has been leveled and filled during construction, but at least one glacial pit can be seen in the woods directly north of the water tower. The pit is about 200 feet in diameter and 15 feet deep.

The west shore of the peninsula, possibly a kame terrace, may have been formed in the following manner: during the retreat of the glaciers at the end of the Ice Age (Pleistocene), a large block

of ice became separated from the main glacier in the area now occupied by Lake Cochituate. This block of stagnant ice melted slowly, and a lake (Lake Cochituate) was formed between the ice and accumulated deposits around it. Sediments deposited by streams flowing into the lake formed lacustrine beds. At a later date, when the ice was completely melted and the surface of the lake had lowered, these beds of stratified lacustrine material collapsed or slumped. Still later, these beds became visible, probably through the actions of weathering and erosion, and some may now be seen at places along the west banks of the peninsula bordering Lake Cochituate. The steep bank, rising 25 feet in places, exposes the horizontal beds of sedimentary material that form the immediate substratum of the site upon which the Center is built. The top 15 to 18 inches consists of soil cover and wind-deposited silt. Below is found about 10 feet of alluvial material, which grades from a medium coarse sand to a gravelly cobble, and below this the remaining portion consists of silty lacustrine deposits. The depth to which these lacustrine beds extend below the lake level is not known.

c. Lake Cochituate

This lake, formed by the glacial processes described above, drains north into the Sudbury River through Cochituate Brook. It has been considerably modified during the period of settlement. The original surface of the lake covered about 450 acres. This was increased to over 650 acres when the lake was converted to a reservoir of the water supply system for Boston. At present, Lake Cochituate is administered by the Massachusetts Department of Natural Resources and is no longer a part of the water supply system. The surface area is now 591 acres. The lake is approximately 3¼ miles long, and averages 22.6 feet in depth. Deeper parts of the middle and upper lake adjacent to the Center average 69.7 feet in depth. The lower lake, to the north, has 7 or 8 acres with depths of 70 feet, and one small spot has a maximum depth of 80 feet (Department of Natural Resources, Commonwealth of Mass., 1952).

The water of Lake Cochituate is slightly turbid, and visibility is usually about 8 feet. The bottom is three-quarters muck and the remainder largely sand and rubble. More than one-half of the shoreline is wooded, and there is relatively little aquatic vegetation.

The source of water for Lake Cochituate is mainly subsurface springs. A few streams, such as Beaverdam, Course, and Snake Brook, flow into the lake but contribute little to the total volume*.

d. Soils

Most of the soils of southern New England are derived from

*Personal communication from Mr. Carl Lydiard, Superintendent of Lake Cochituate State Park, Massachusetts Department of Natural Resources.

glacial material. Nearly all have been podzolized* to some degree and are acidic. In the northern parts of New England true podzols occur, but in the central and southern parts of the region (including Massachusetts) most of the soils may be classed as brown or gray-brown podzolic soils. Gray-brown podzols have a thin mat of partly decayed leaves over a very thin dark grayish-brown humus-mineral soil. These soils are developed under deciduous or mixed deciduous and coniferous forest in temperate or cool-temperate humid regions. In eastern Massachusetts, where the forest cover is either mixed (coniferous-deciduous) or predominantly deciduous, soils are less acid than those of the true podzols farther north.

The soils in the Natick region are of the Gloucester-Plymouth Association (USDA Yearbook, 1939), which is found widely scattered over rolling land from the Maine coast to Connecticut. The Gloucester series predominates in the Natick area. It develops under cool temperate conditions from parent materials of glacial till and outwash materials, mainly from granite and gneiss. Much of the land covered by this association is very stony and forested, though there are many areas of farmed land and pastures.

Where forested, Gloucester loam has a surface covering of leaf mold about 1 inch thick. This rests on dark-brown light loam, 1 or 2 inches thick, which grades into light-brown loam or heavy fine sandy loam which continues downward for 2 or 3 inches before it grades into the subsoil. In cleared areas the soil, to a depth of 6 or 8 inches, is dark-brown light loam or heavy fine sandy loam underlaid by yellowish-brown, friable, medium-textured loam. At a depth of 18 or 20 inches, the subsoil grades downward into yellow, slightly compact loam or sandy loam. Some gravel, small stones, and boulders are scattered on the surface and throughout the soil (Latimer and Lanphear, 1924). Many of these loose stones are piled into fences that surround the fields.

5. Vegetation

Natick lies within the northeastern hardwood forest (Shantz and Zon, 1924). The original composition of the stands has been considerably altered during a long period of settlement. Trees within the Center are mostly second or later growth, with few, if any, exceeding 75 years in age. The diversity of physical conditions gives rise to a corresponding variety in the character of the vegetation.

During construction of the Center, a large percentage of the land was cleared, spread with silt topsoil, filled, and leveled. A few

*Podzols are soils having an organic mat and a very thin organic-mineral layer above a gray leached layer which rests upon a dark-brown layer into which the leached material has been deposited (illuvial layer). It is developed under the coniferous or mixed forest in a temperate to cold moist climate (USDA Yearbook, 1939).

scattered trees and small patches of woods were left as landscaping. Most of the cleared area not used for buildings and roads is seeded in lawn. A former gravel pit, north of the main part of the center, has been leveled, partly surfaced with asphalt, and the wide slopes planted in grass.

The western edge of the peninsula and the land south of the Research Building and Climatic Research Laboratory still retain a natural vegetation cover, although in some places the understory of shrubs has been cleared away (Fig. 16). This vegetation consists primarily of various species of oak, including black, white, and red oak. Other hardwoods scattered throughout the woods are red maple, American elm, and gray birch. Conifers are represented by a stand of white pine in the low-lying area along the southwest shore of the peninsula, and by young white pines interspersed among the hardwoods. In addition to the white pines, a few pitch pines grow on the site.

Figure 16: Woods on western edge of peninsula.
Note lack of undergrowth.

Most of the deciduous species lose their leaves in October or November, but the dry leaves of the white and black oak persist through the winter. Leafing out usually begins in early May, and is well advanced by June. Pines lose some leaves (needles) in winter, but their greatest loss of old needles occurs in spring and fall, when new foliage appears.

The marshes along the shores of the eastern bay and along the edges of the small pond to the north of Kansas Street consist largely of

marsh sedges, cat-tail, and occasional small willows and other shrubs (Fig. 17).

Figure 17: Marsh on eastern shore of the peninsula.

6. Acknowledgments

Appreciation is expressed to Dr. Charles F. Brooks, Mr. Charles Cuniff, and other members of the Harvard Blue Hill Observatory, for data and advice relating to radiation and sunshine; to personnel of the Framingham Office, Metropolitan Water Works, Massachusetts District Commission, for making available records of temperature and precipitation for the Lake Cochituate station; to Dr. Joseph Hartshorn, U. S. Geological Survey, for conducting a brief field study of the geology and geomorphology of Natick and vicinity; to Mr. Carl Lydiard, Massachusetts Dept. of Natural Resources, for providing data and information related to Lake Cochituate; to the Directorate of Climatology, Air Weather Service, USAF, for providing climatic statistics for Hanscom Air Force Base; to Mr. Gerald MacDonald, Chief, and Dr. Ernest Kenyon, Testing Office, QM R&E Command, for providing information on test facilities; to Mr. Eugene S. Cotton for information concerning the solar furnace; to Mr. Benjamin Malin and Mr. Edwin Zelesny for information pertaining to the Rain Tower and Climatic Research Laboratory; to PFC George Barth for assisting in the field study of geology and geomorphology and in the preparation of the section on topography; to Mr. Owen Parmele for assisting with statistical computations; to Mr. Jameson D. MacFarland, Miss Elizabeth Mason, Mr. Roland Frodigh, and Mr. Donald Cox for preparing graphs, charts, and maps included in this report.

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APPENDIX

TABLES AND GRAPHS OF CLIMATIC DATA

TEMPERATURE REGIME
Lake Cochituate Station
Natick, Massachusetts
Length of Record: 25 years

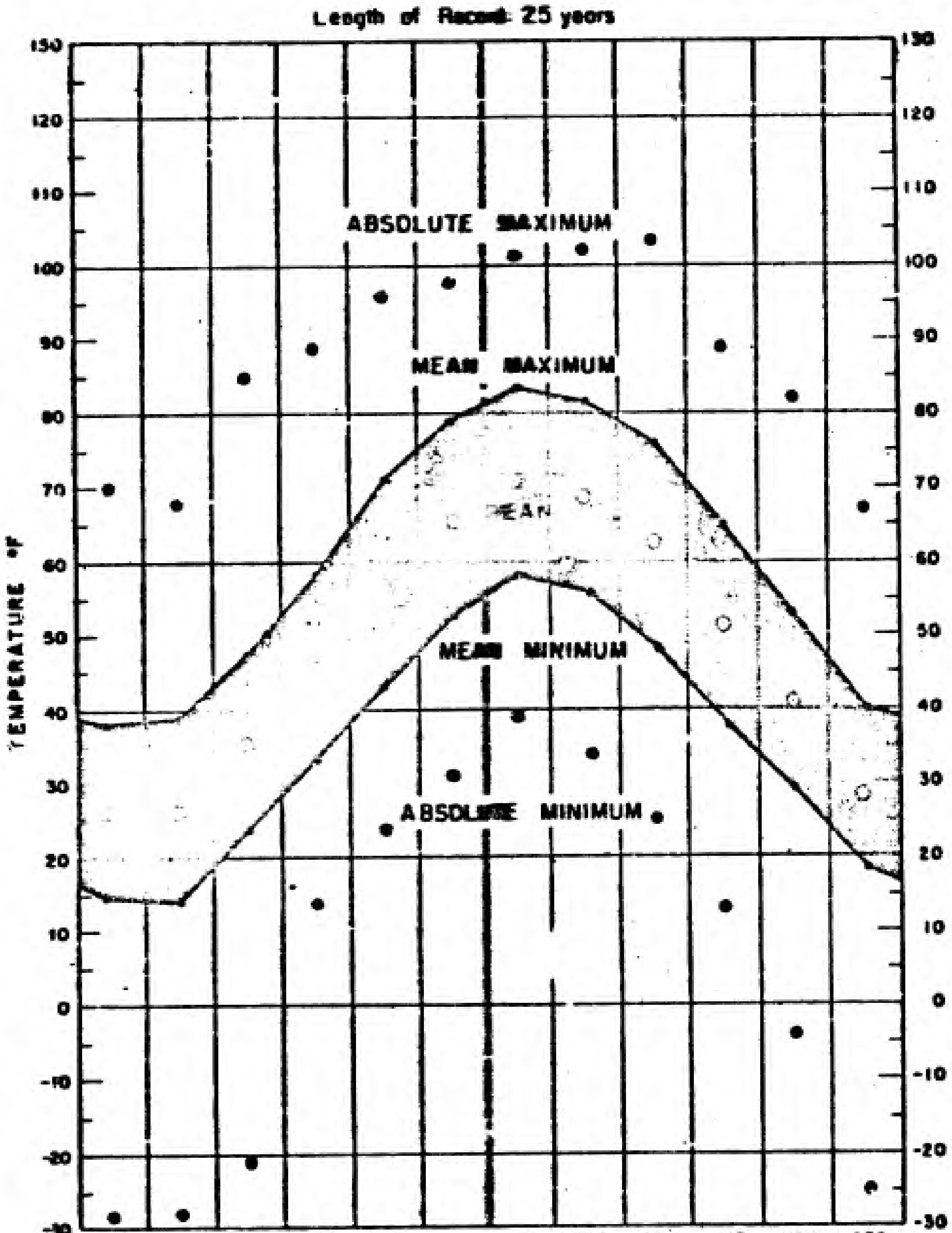
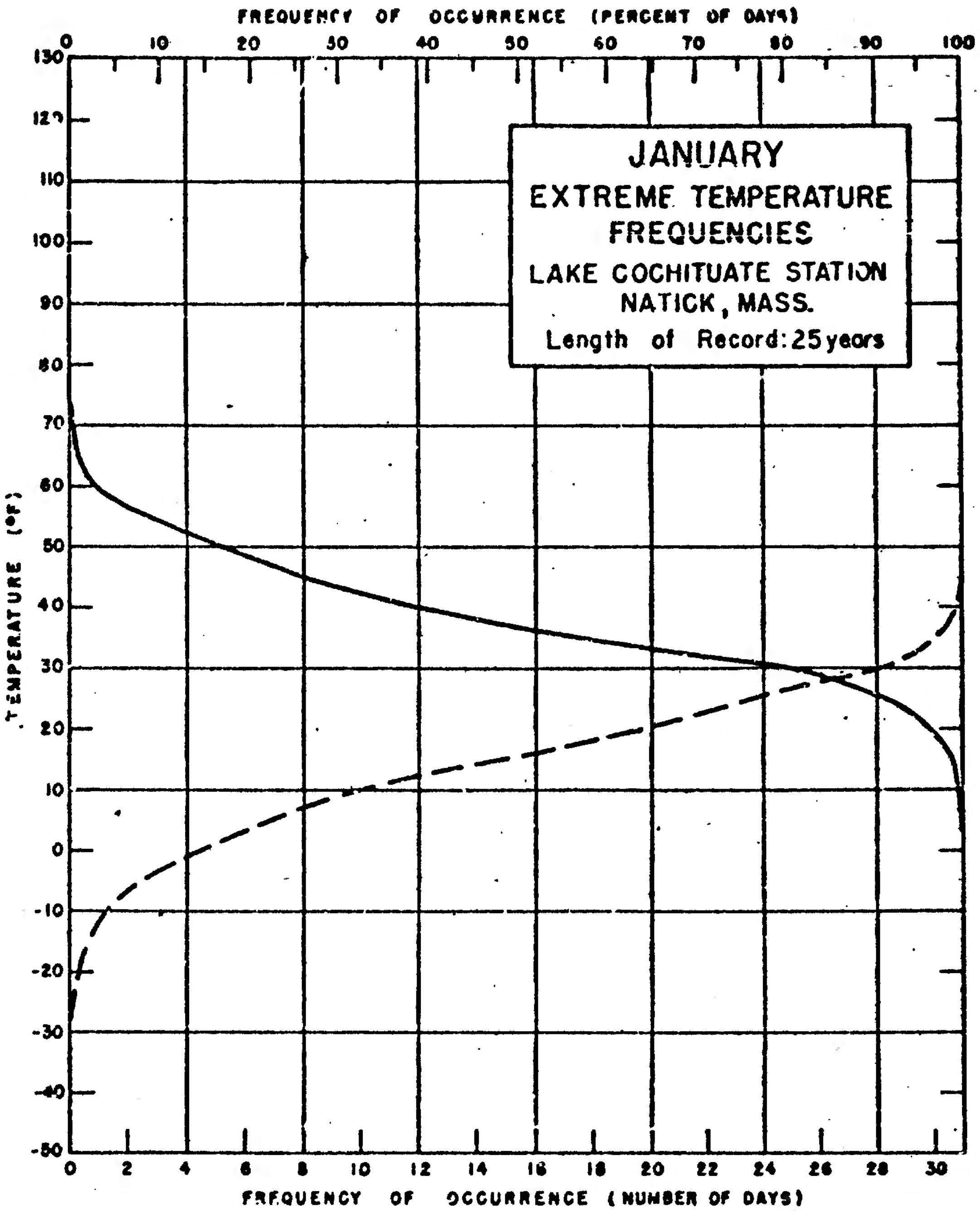


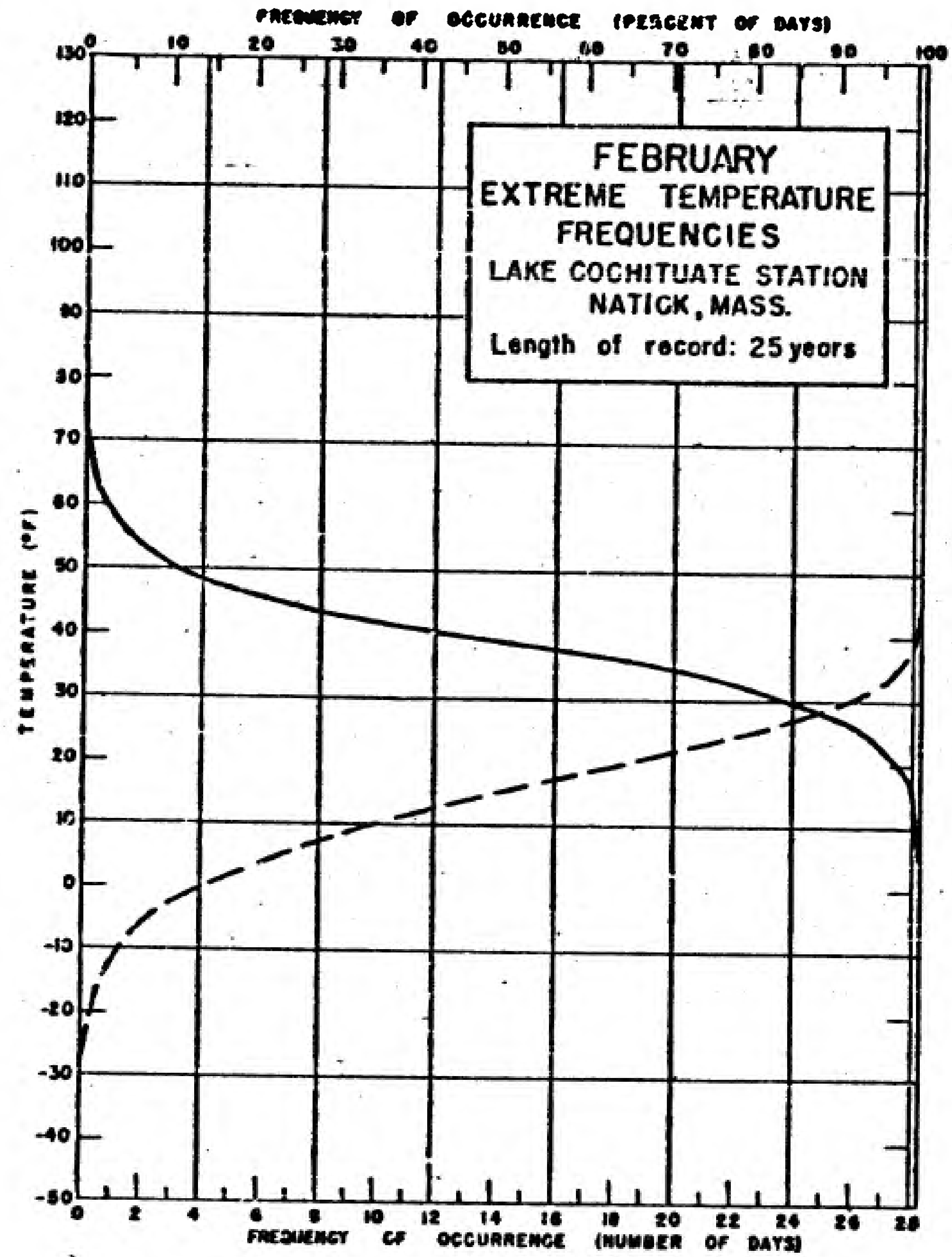
Figure 18



—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

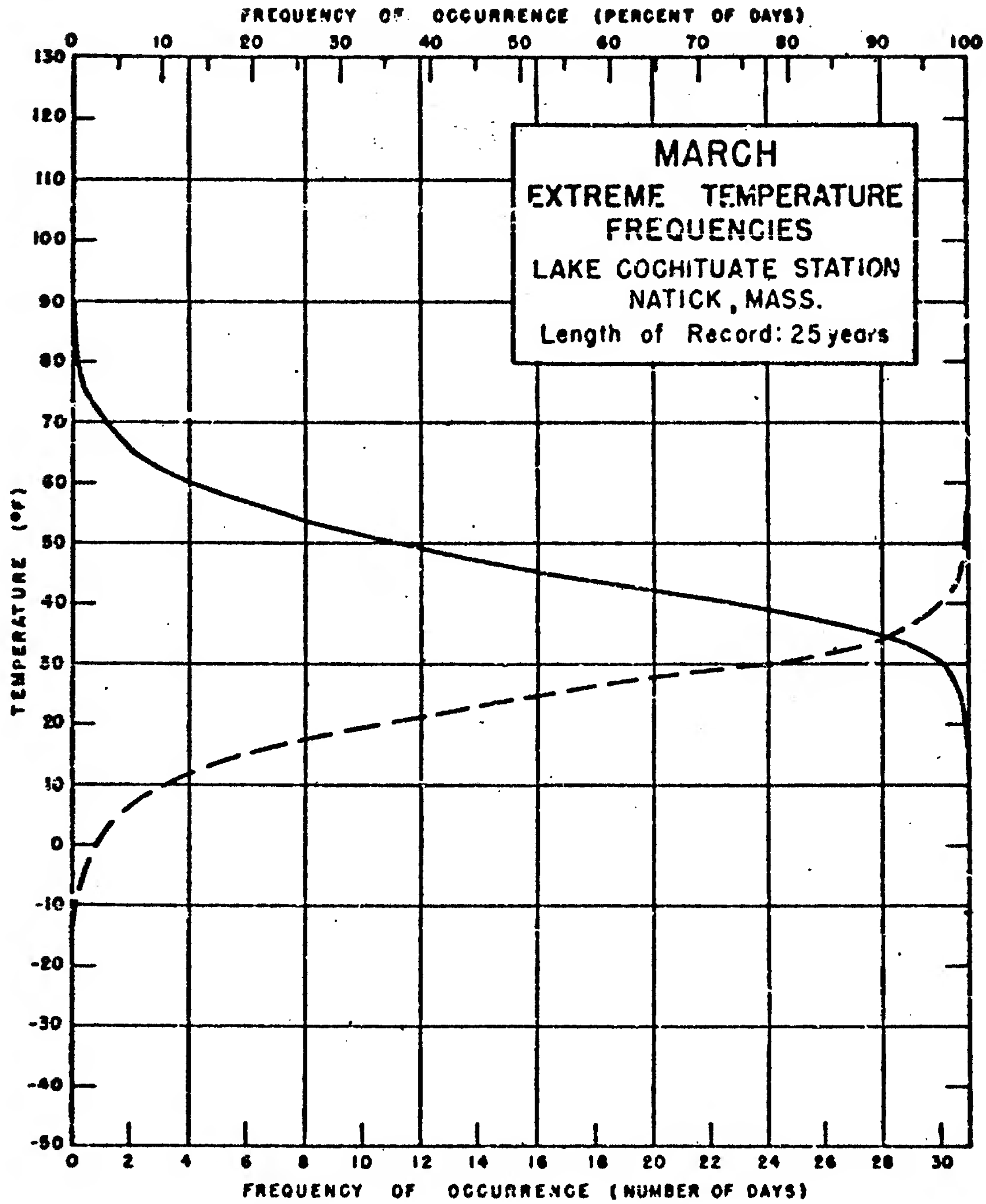
Figure 19



—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

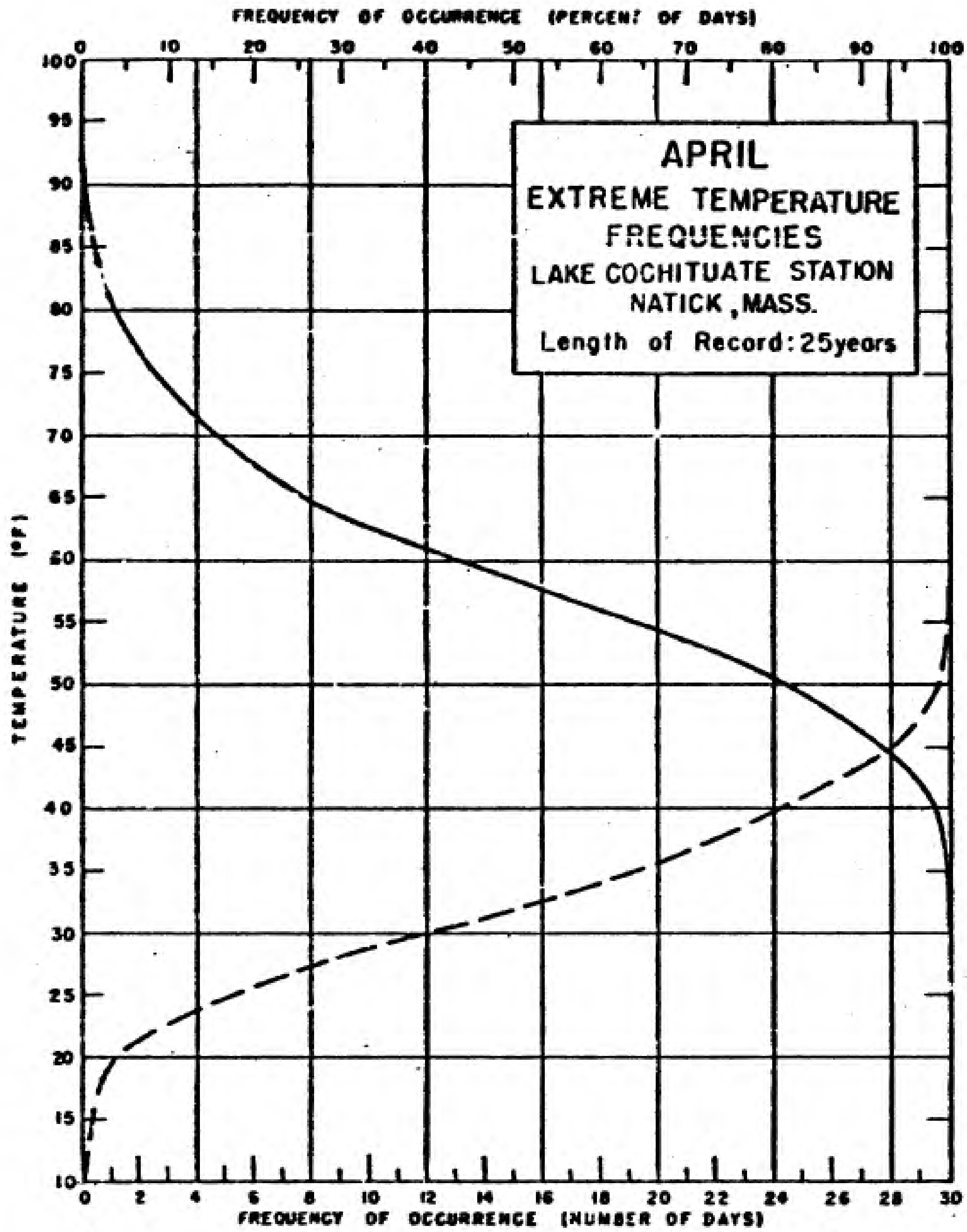
Figure 20



——— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

— — Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 21



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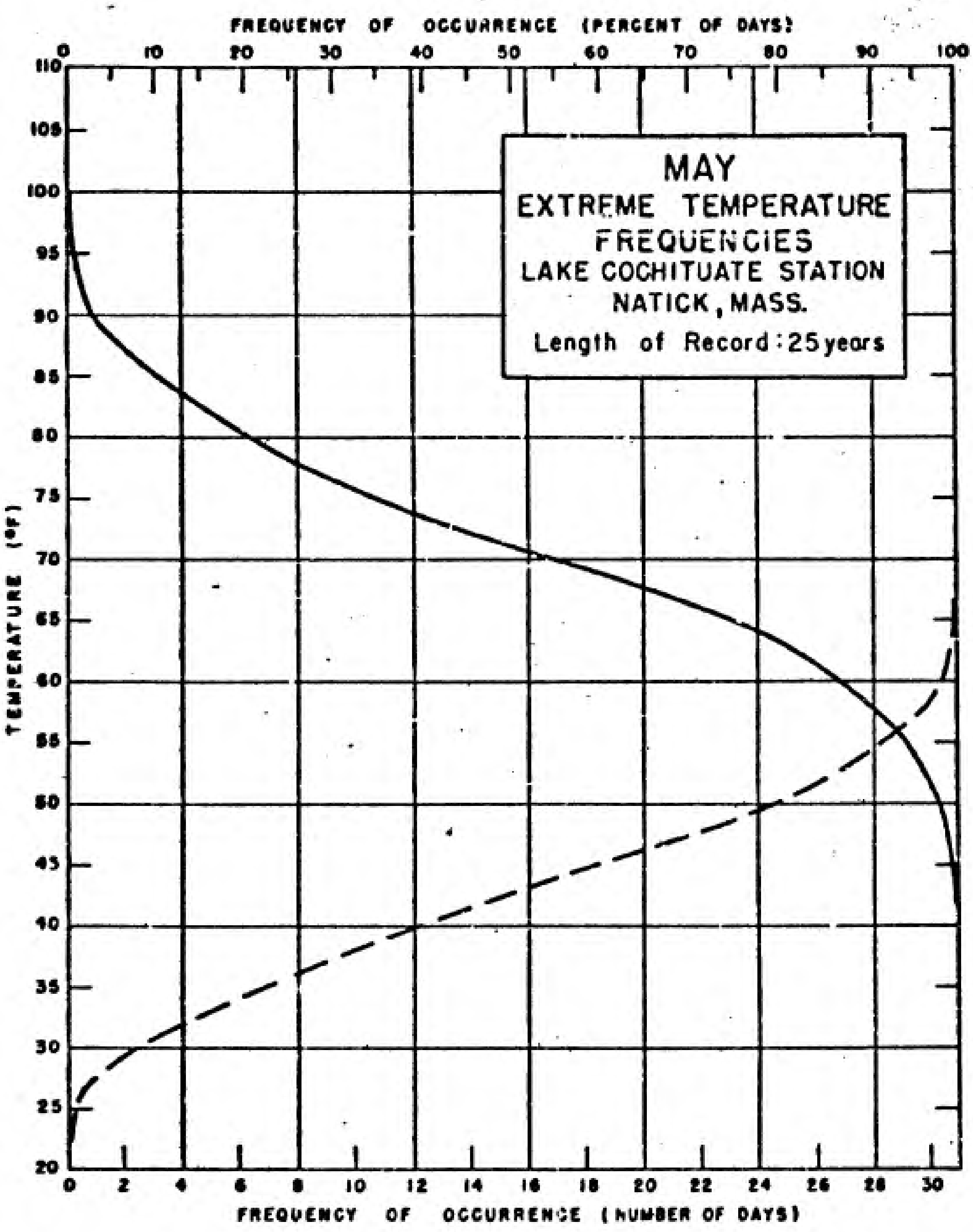
– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 22



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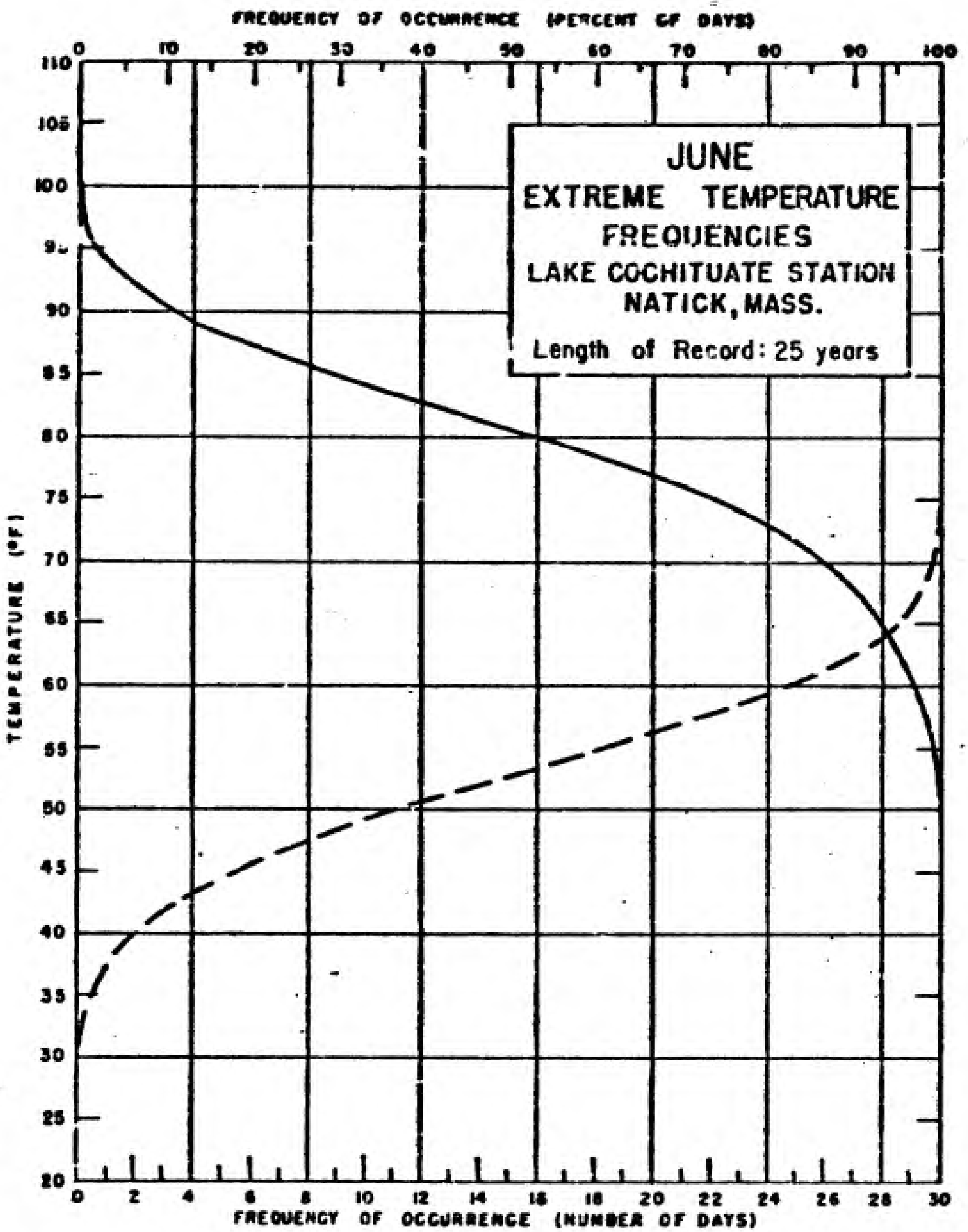
– – – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 23



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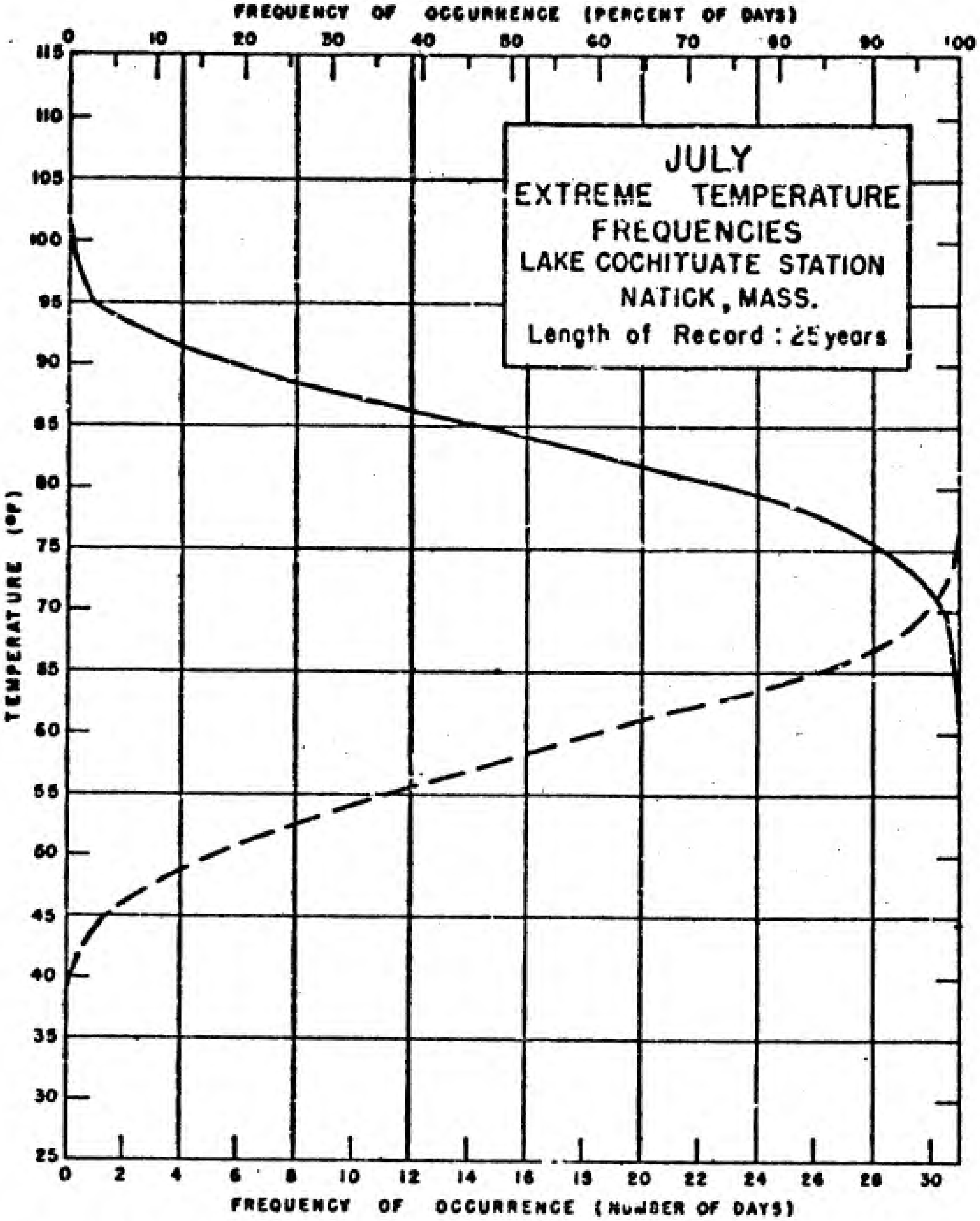
– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

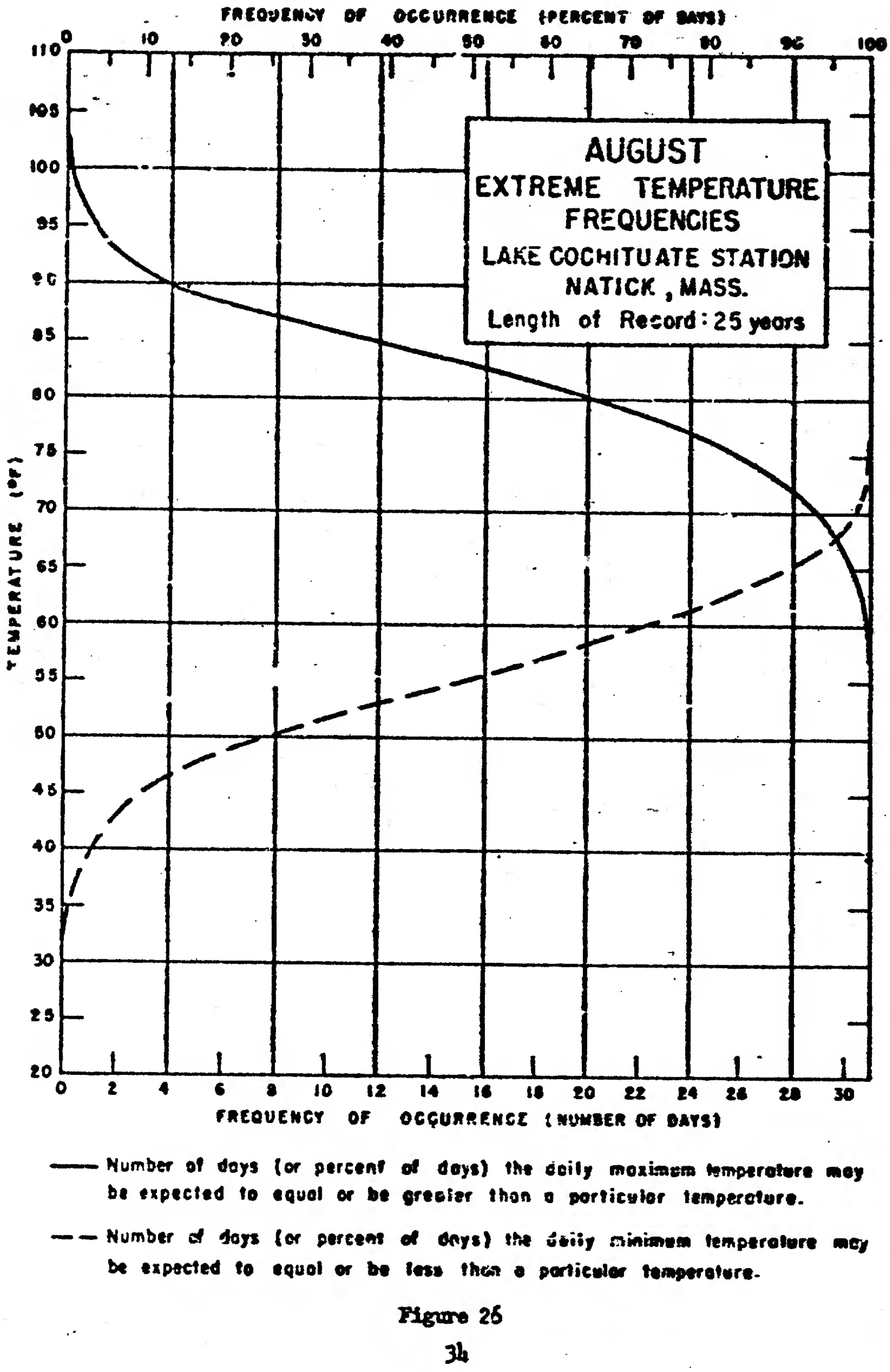
Figure 24



—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

— — Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

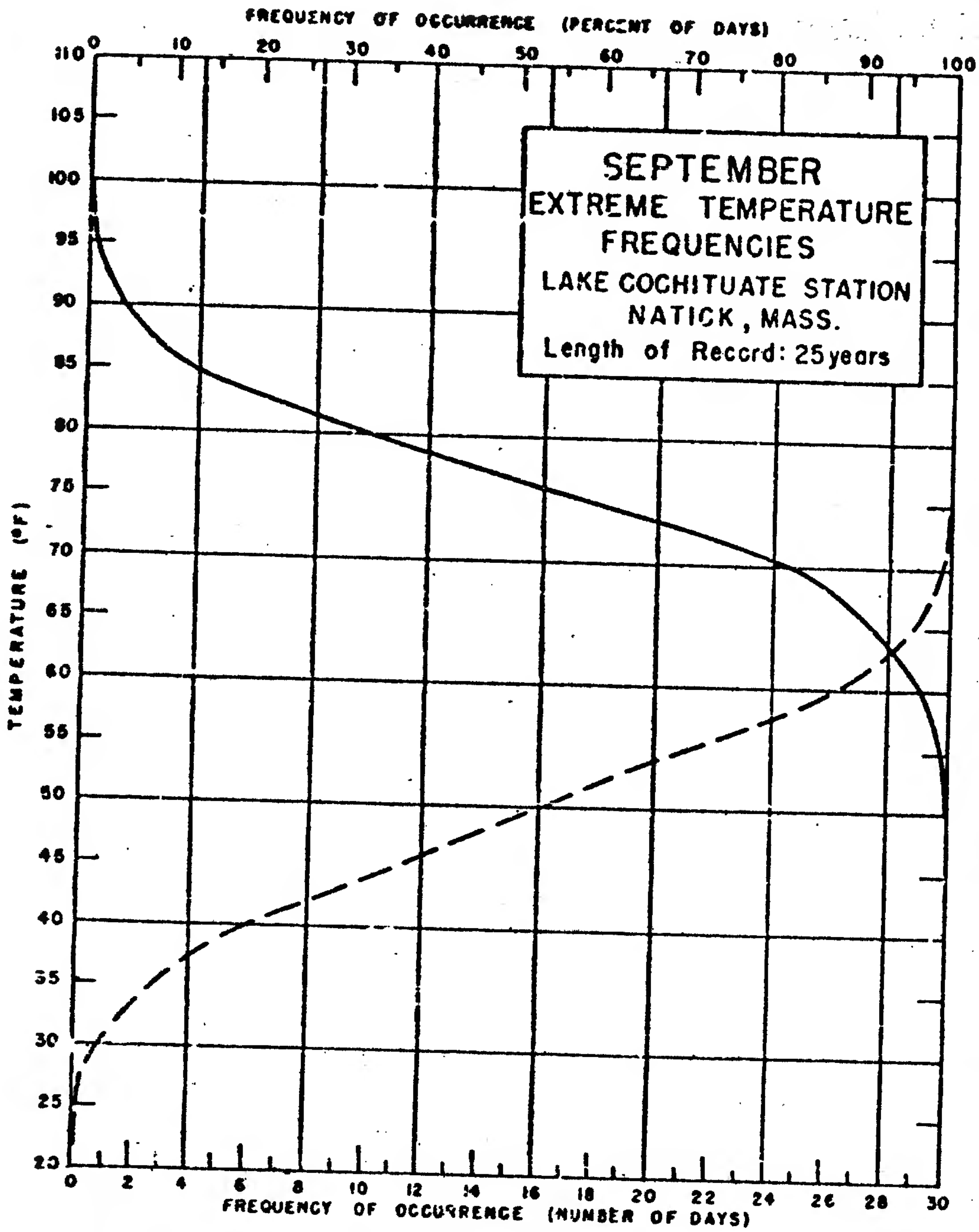
Figure 25



—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 26



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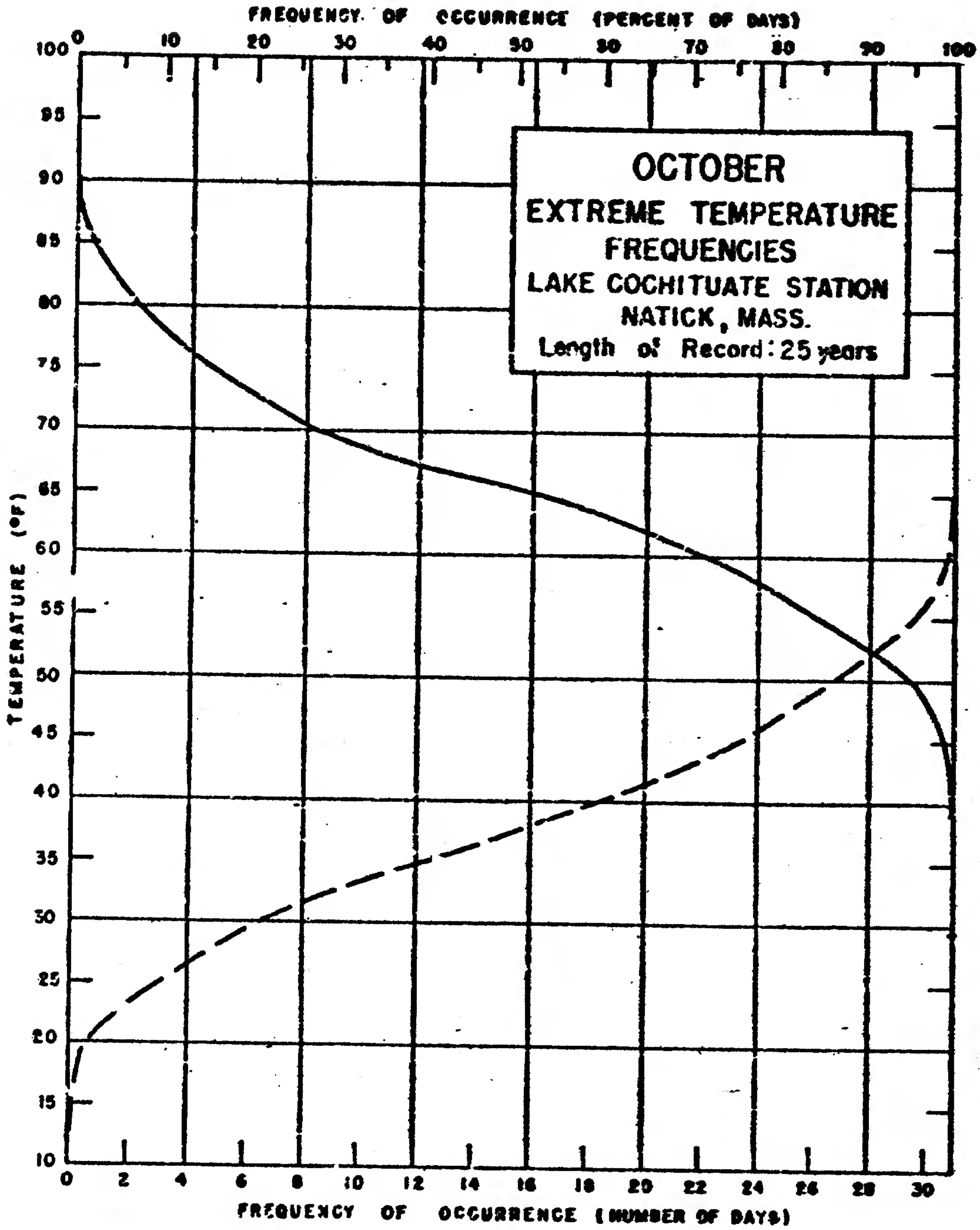
– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 27



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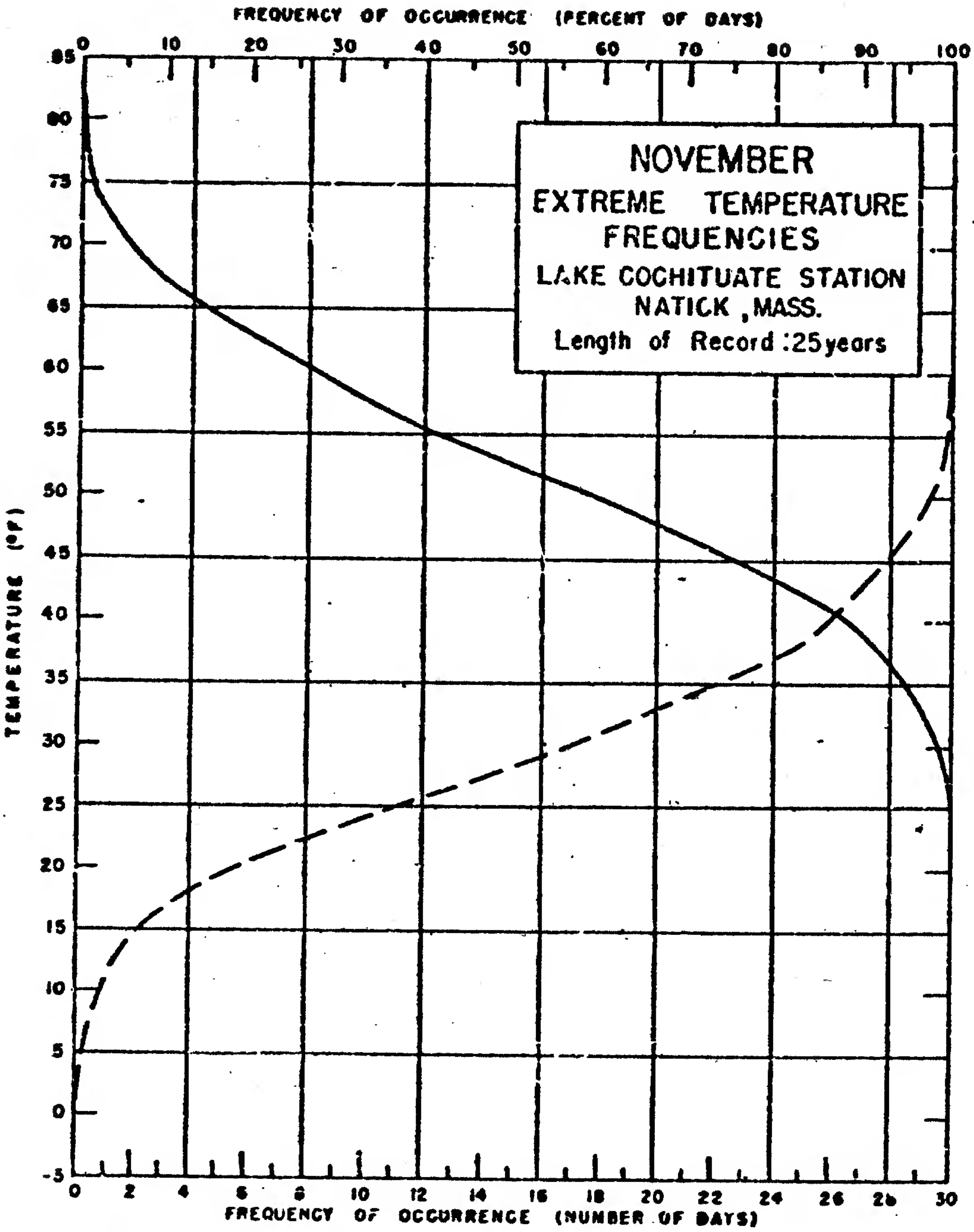
– – – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 28



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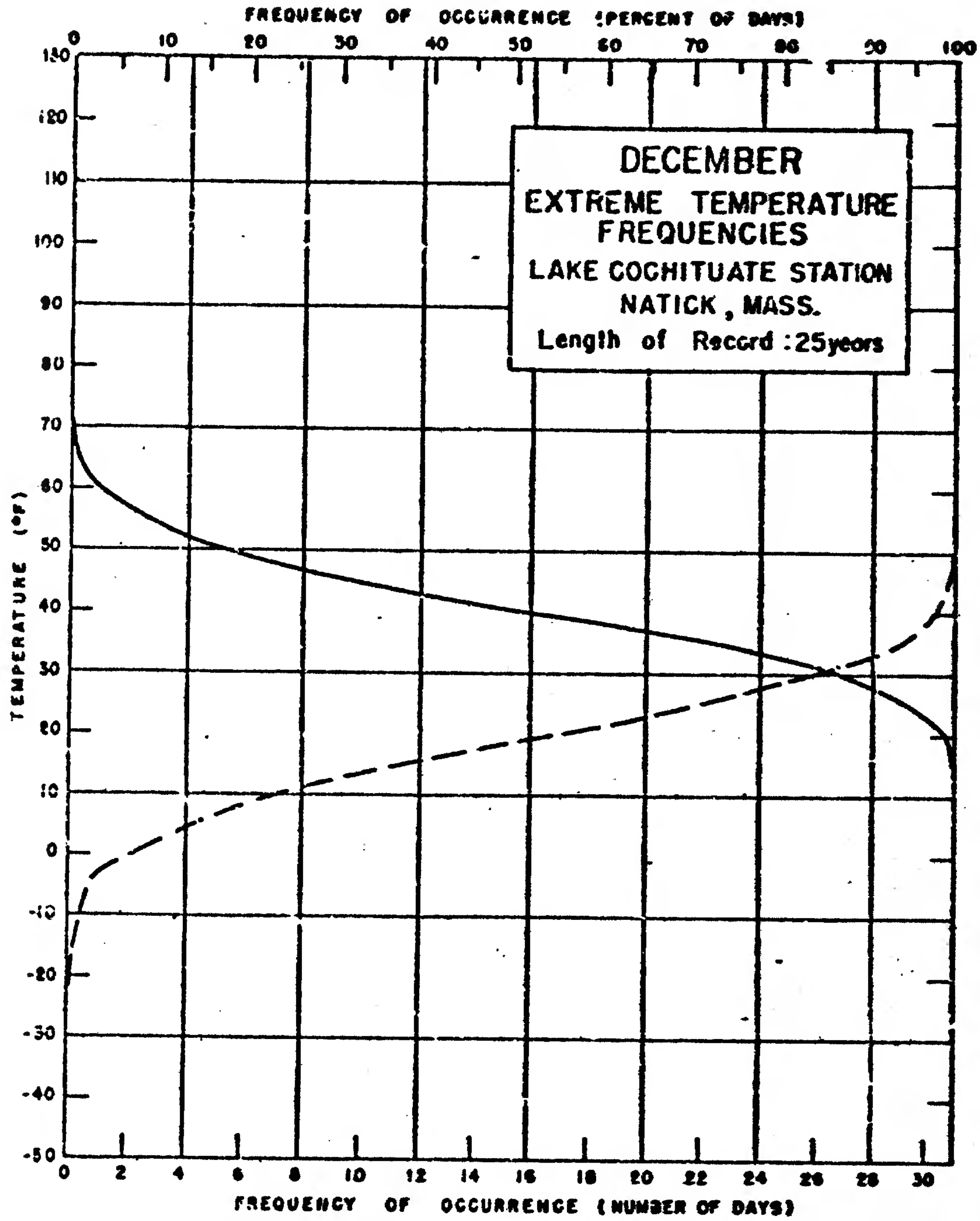
– – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 29



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– – – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Figure 30

TABLE I: STANDARD DEVIATIONS FROM MEAN TEMPERATURES (F°)
LAKE COCHITUATE STATION
Natick, Mass.
Length of Record: 25 Years

	Mean Daily Maximum		Mean		Mean Daily Minimum	
	Temp.	SD	Temp.	SD	Temp.	SD
January	38.1	5.3	26.5	5.5	15.0	5.9
February	39.0	4.0	26.5	4.4	14.1	5.4
March	47.5	4.9	35.7	4.0	23.8	3.4
April	58.4	3.6	45.7	2.8	33.1	2.7
May	71.0	3.7	57.2	2.4	43.4	2.0
June	79.3	3.3	65.9	2.3	52.5	1.9
July	83.7	2.4	70.8	1.7	57.9	2.1
August	81.9	3.3	68.9	2.7	55.9	2.5
September	76.1	1.8	62.5	1.6	48.9	2.3
October	65.0	3.4	51.6	2.5	38.2	2.3
November	52.8	4.1	41.1	2.9	29.3	2.8
December	40.2	4.8	29.4	3.6	18.6	3.2

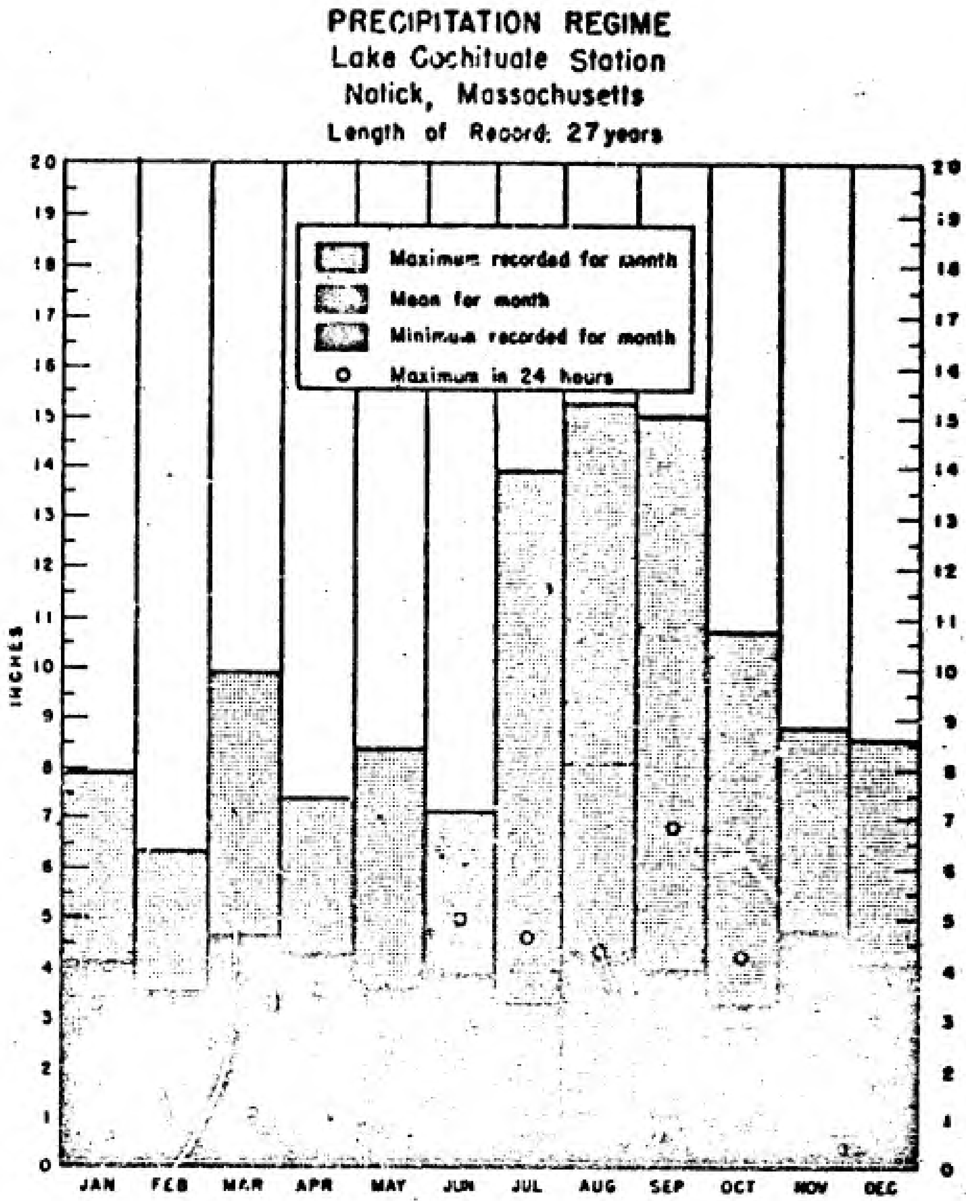
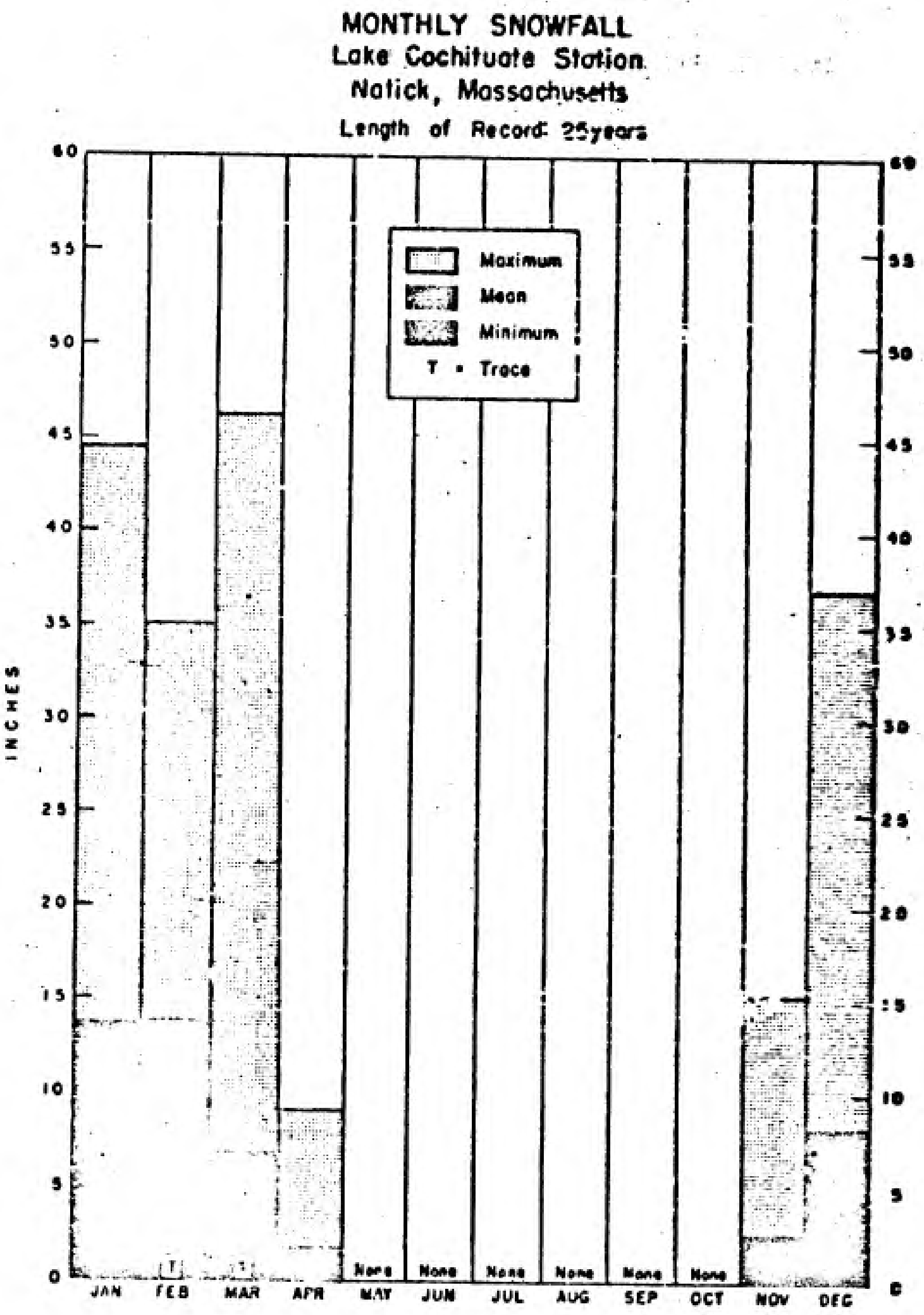

PRECIPITATION REGIME
Lake Cochituate Station
Natick, Massachusetts
Length of Record: 27 years
Maximum recorded for month
Mean for month
Minimum recorded for month
Maximum in 24 hours
INCHES
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 31

TABLE II: PRECIPITATION MEANS AND EXTREMES (inches)
LAKE COCHITUATE STATION
Natick, Mass.
Length of Record: 27 Years

	Mean in Month	Max. in Month	Min. in Month	Max. in Day	No. of Days ≥ 0.01	Mean Snowfall
January	4.13	7.91	0.82	3.27	10	13.7
February	3.50	6.38	1.46	2.47	8	13.8
March	4.68	9.63	1.92	3.80	10	6.8
April	4.18	7.40	1.47	3.57	10	1.2
May	3.62	8.44	0.91	2.35	10	0.0
June	3.83	7.11	1.09	4.98	9	0.0
July	3.36	13.91	0.72	4.64	9	0.0
August	4.21	15.35	1.17	5.40	8	0.0
September	4.01	15.02	0.60	6.90	8	0.0
October	3.36	10.71	0.44	4.28	8	0.0
November	4.76	8.81	0.95	3.88	9	2.5
December	4.13	8.64	1.09	3.77	8	8.2
TOTAL	47.77					46.2



MONTHLY SNOWFALL
Lake Cochituate Station
Natick, Massachusetts
Length of Record: 25years
INCHES
Maximum
Mean
Minimum
T = Trace
None
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 32

TABLE III: SNOW DEPTH
Hanscom AFB
Bedford, Mass.

Period of Record: 1946 - 1953*

Month	None	Trace	1 in.	2 in.	3 in.	4-6 in.	7-12 in.	13-24 in.	25-36 in.	37-48 in.	Total Days	Mean No. of Days with Measur. Amt.
			Frequency of Occurrence (days)									
January	92	22	14	11	12	35	27	21	8	3	248	16.4
February	83	17	17	17	20	27	29	9	7	0	226	15.6
March	181	12	15	7	5	17	8	3	0	0	248	6.9
April	234	1	1	1	0	2	0	0	0	0	239	0.5
May	247	0	0	0	0	0	0	0	0	0	247	0.0
June	240	0	0	0	0	0	0	0	0	0	240	0.0
July	248	0	0	0	0	0	0	0	0	0	248	0.0
August	248	0	0	0	0	0	0	0	0	0	248	0.0
September	240	0	0	0	0	0	0	0	0	0	240	0.0
October	217	0	0	0	0	0	0	0	0	0	217	0.0
November	201	2	3	3	0	0	0	0	0	0	209	0.9
December	141	14	15	12	6	14	6	5	3	0	216	8.0

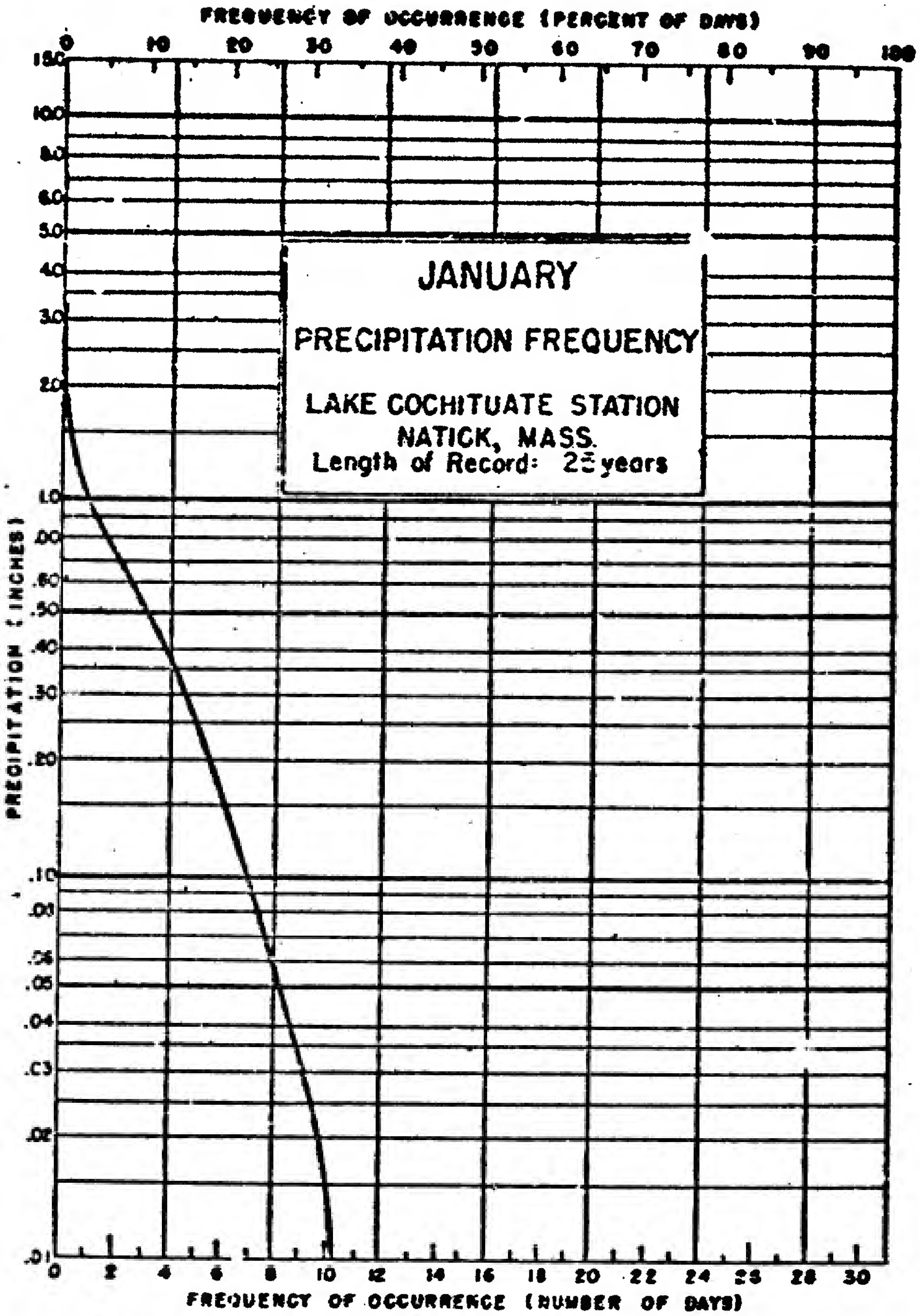
*Snow depth observations taken at 0030 GCT (1930 LST) through June 1952, and at 1230 GCT (0730 LST), from July 1952 to September 1953.

TABLE 17: STANDARD DEVIATIONS FROM MEAN PRECIPITATION* AND SNOWFALL
Lake Cochituate Station
Natick, Mass.

Length of record: 27 years for precipitation
25 years for snowfall

Month	Precipitation (inches)		Snowfall (inches)	
	Mean	SD	Mean	SD
January	4.13	1.72	13.7	10.2
February	3.50	1.08	13.8	7.8
March	4.68	1.99	6.8	6.1
April	4.18	1.63	1.2	2.7
May	3.62	1.78	0.0	0.0
June	3.83	1.74	0.0	0.0
July	3.36	2.69	0.0	0.0
August	4.21	3.04	0.0	0.0
September	4.01	3.55	0.0	0.0
October	3.36	2.30	0.0	0.0
November	4.76	2.53	2.5	4.3
December	4.13	1.92	8.2	9.3

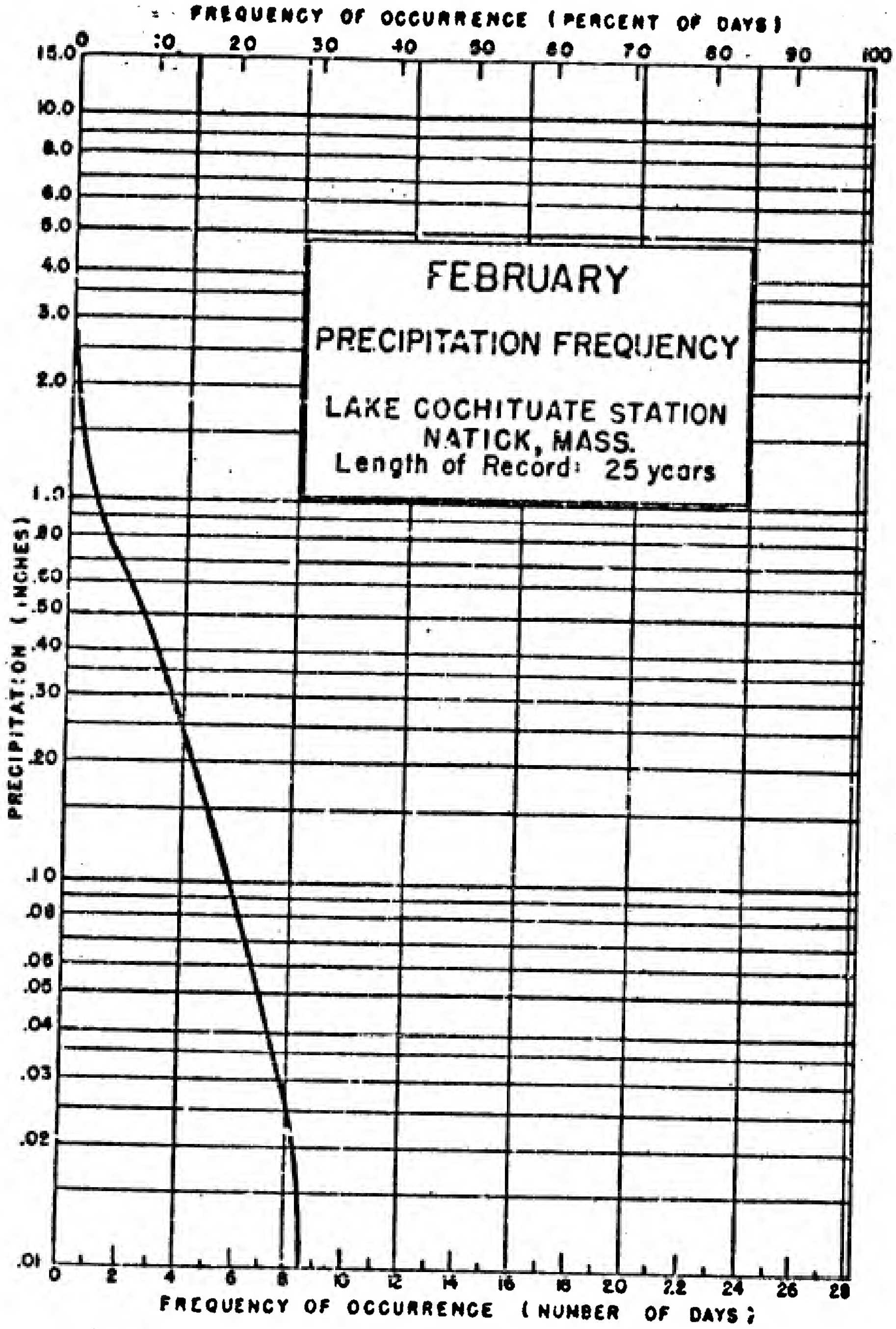
*Includes snowfall, water equivalent



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.06 inches or more precipitation may be expected to occur 8 days during January (or approximately 26 percent of the days).

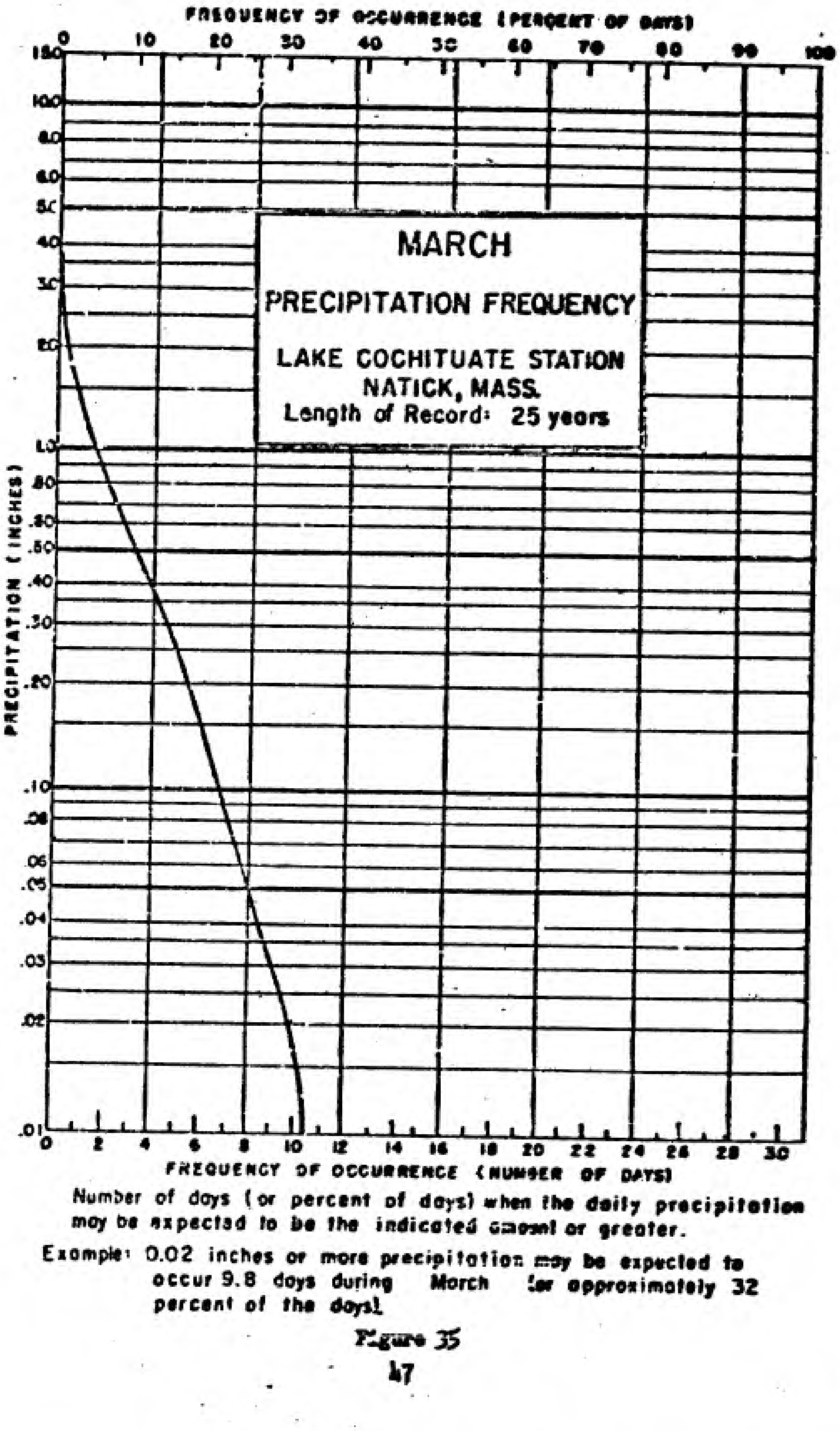
Figure 33



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.26 inches or more precipitation may be expected to occur 4 days during February (or approximately 15 percent of the days).

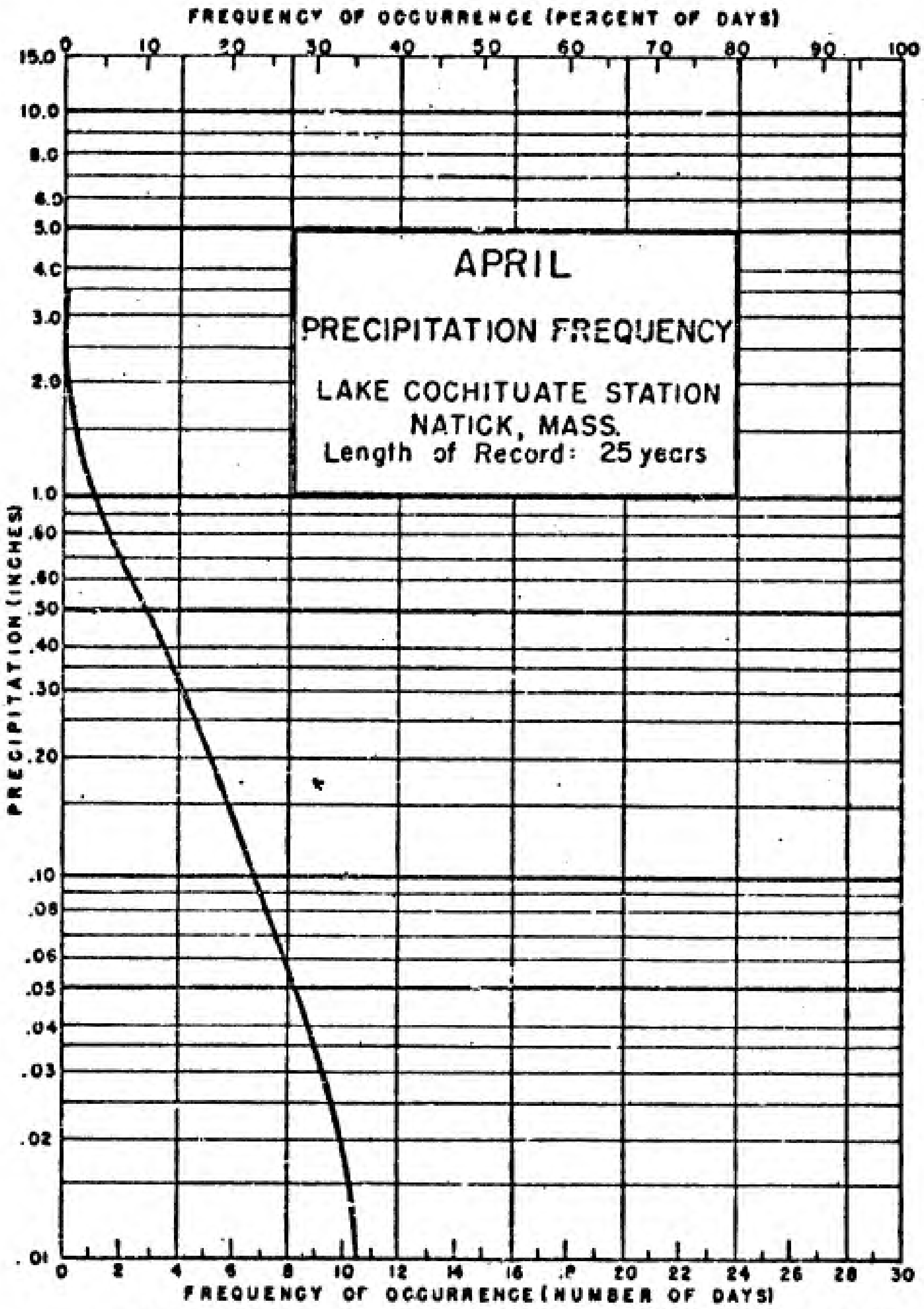
Figure 34



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.02 inches or more precipitation may be expected to occur 9.8 days during March (or approximately 32 percent of the days).

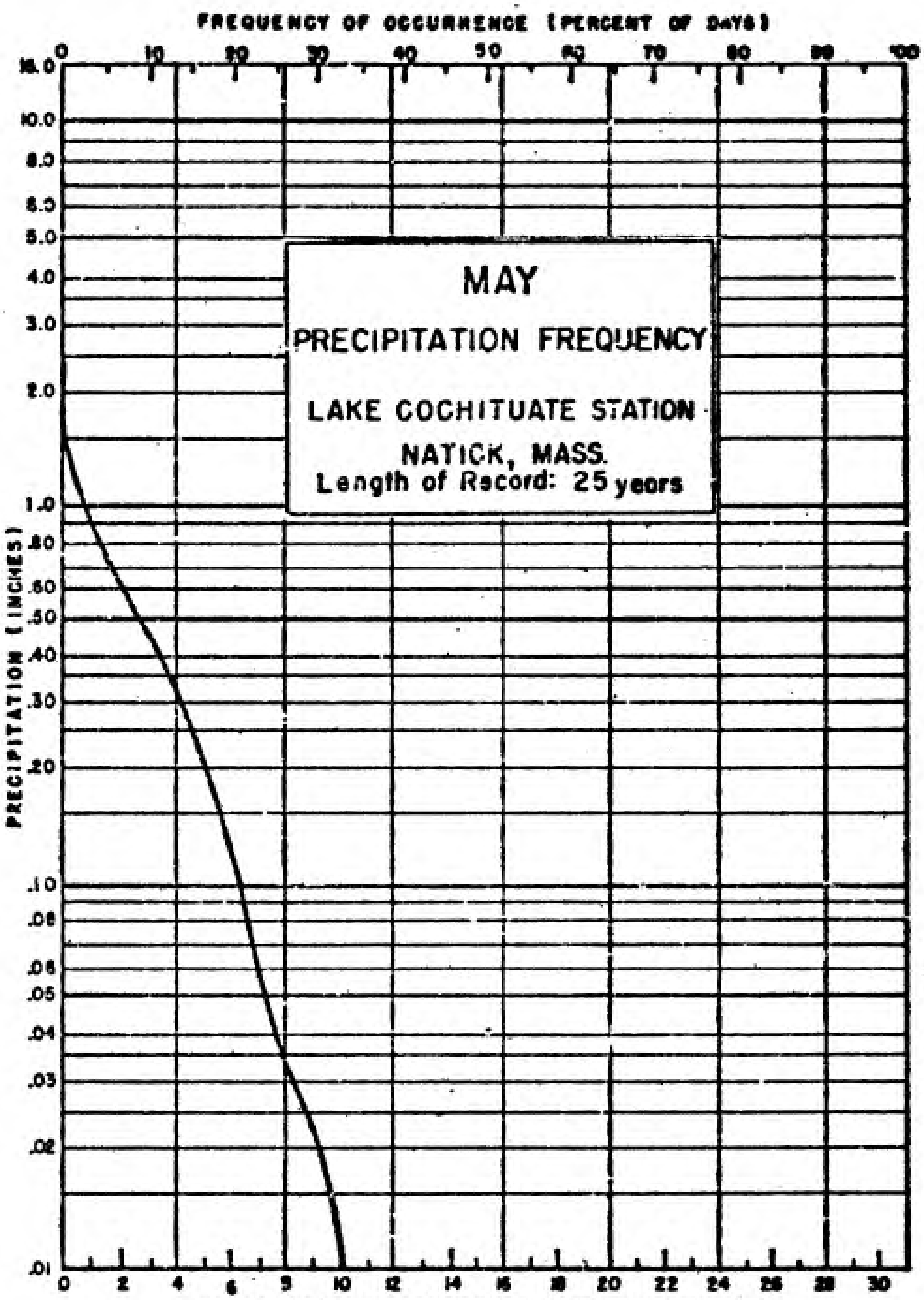
Figure 35



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.11 inches or more precipitation may be expected to occur 6.2 days during April (or approximately 23 percent of the days).

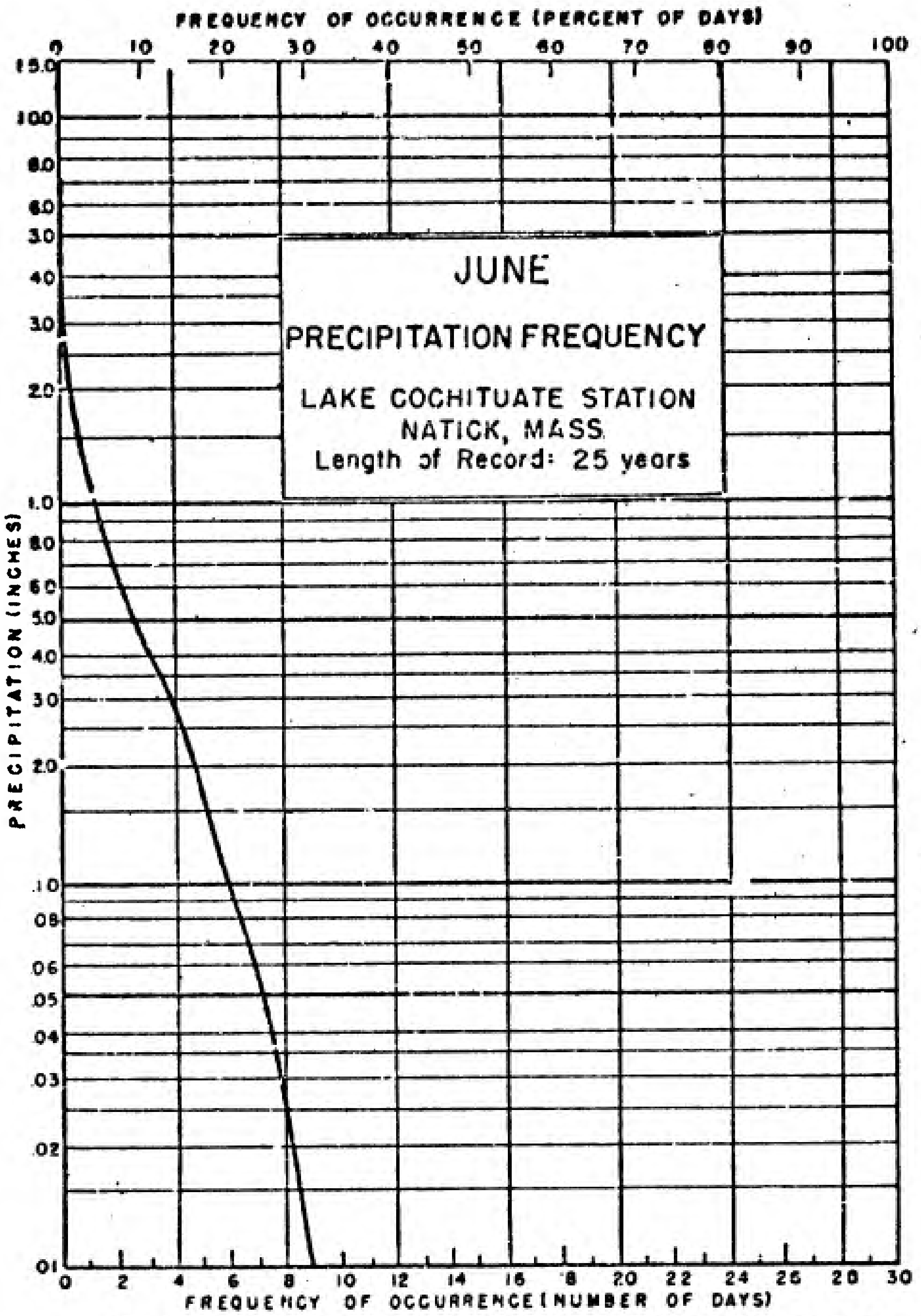
Figure 36



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.02 inches or more precipitation may be expected to occur 9 days during May (or approximately 29 percent of the days).

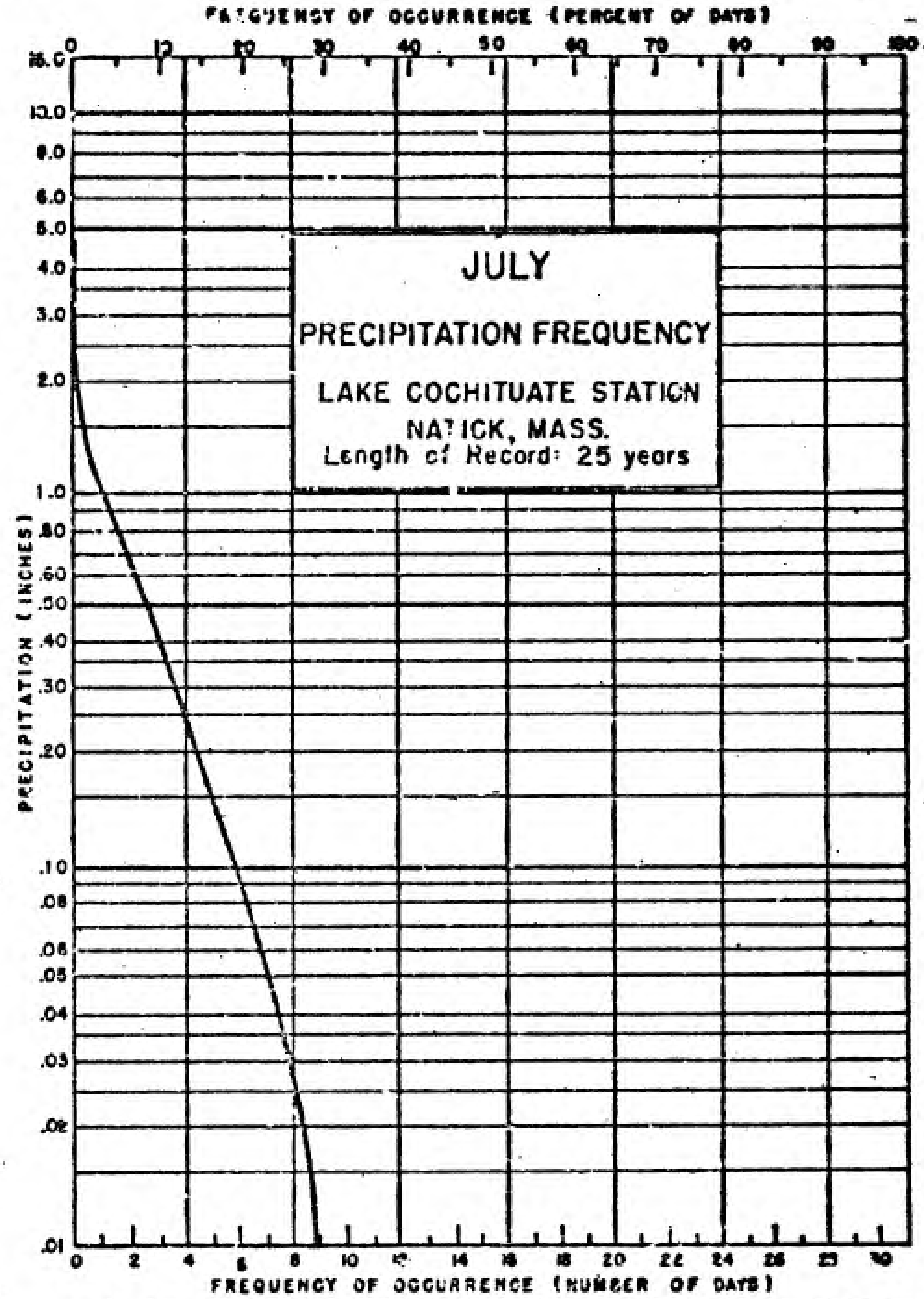
Figure 37



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.26 inches or more precipitation may be expected to occur 4.2 days during June (or approximately 15 percent of the days).

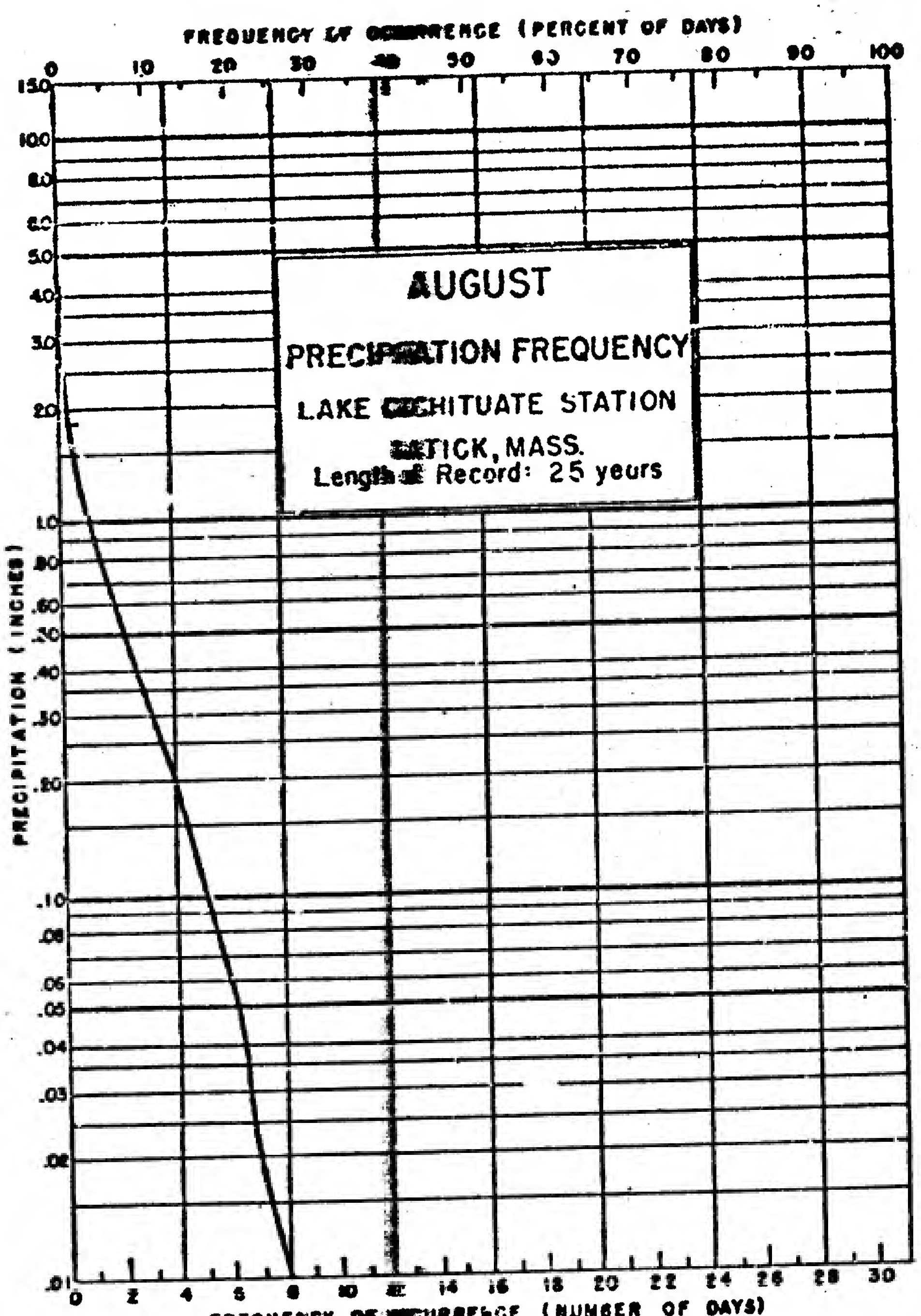
Figure 38



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.1 inches or more precipitation may be expected to occur 5.7 days during July (or approximately 17 percent of the days).

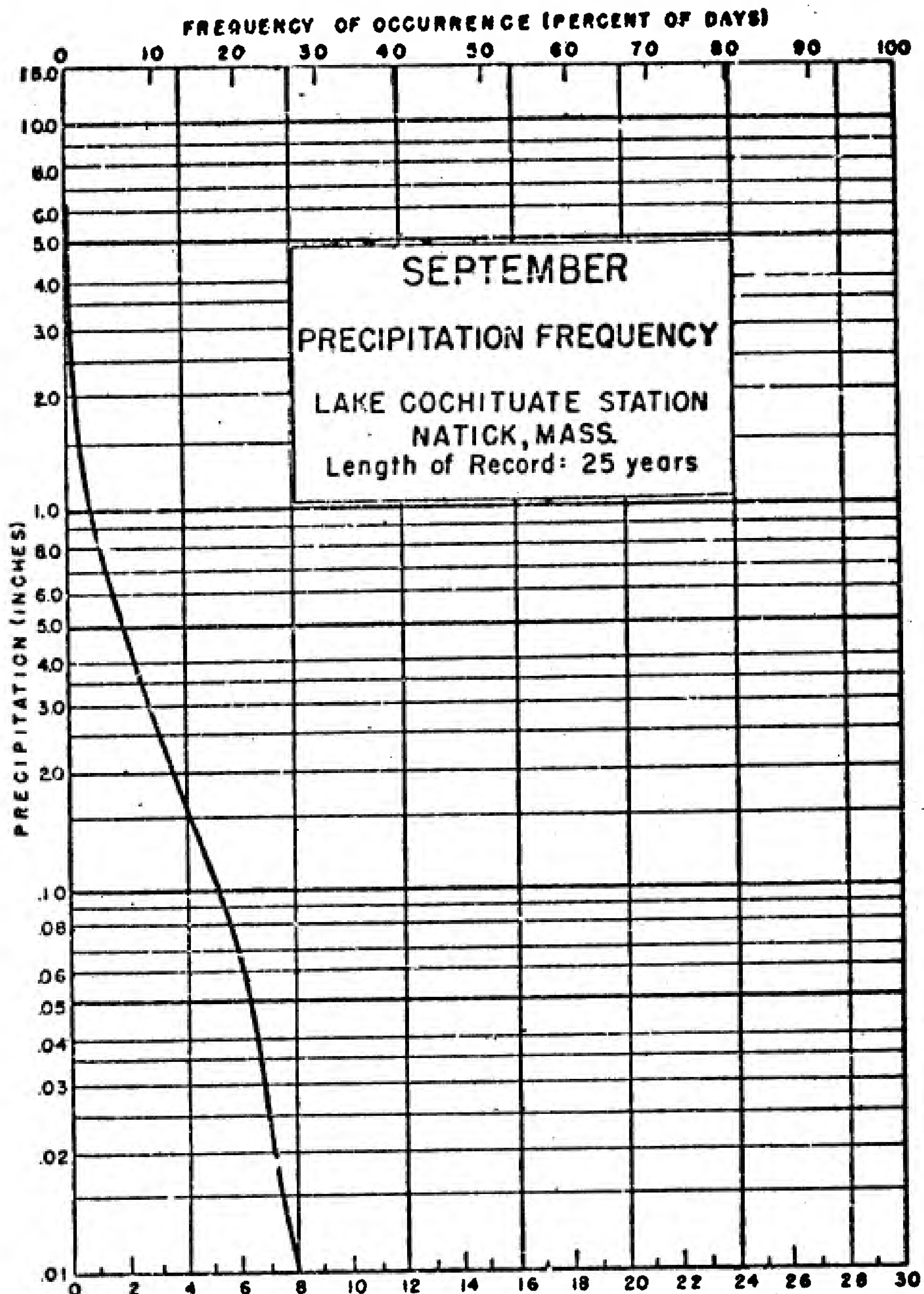
Figure 39



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.06 inches or more precipitation may be expected to occur 6 days during August (or approximately 19 percent of the days).

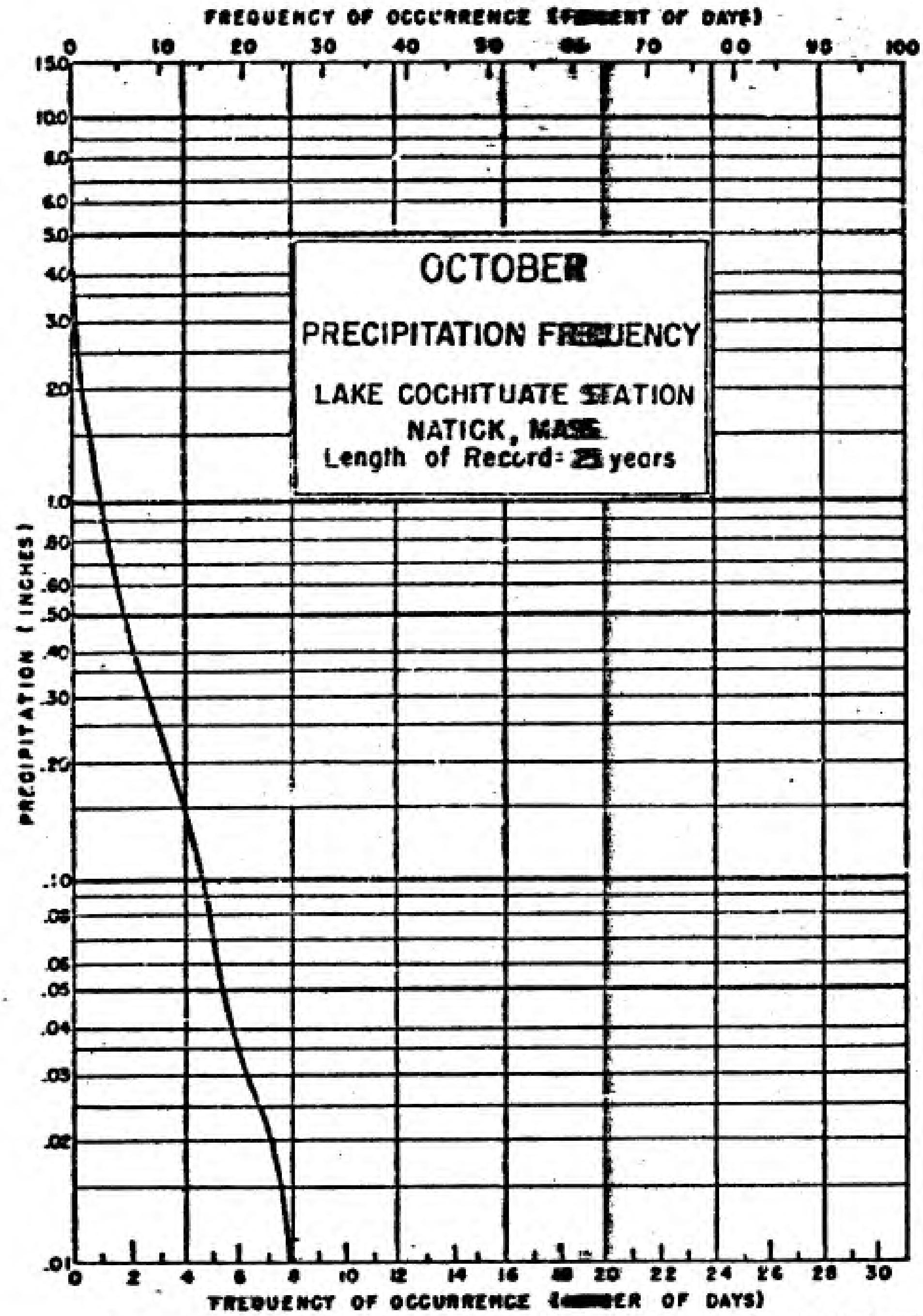
Figure 40



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.11 inches or more precipitation may be expected to occur 4.9 days during September (or approximately 17 percent of the days).

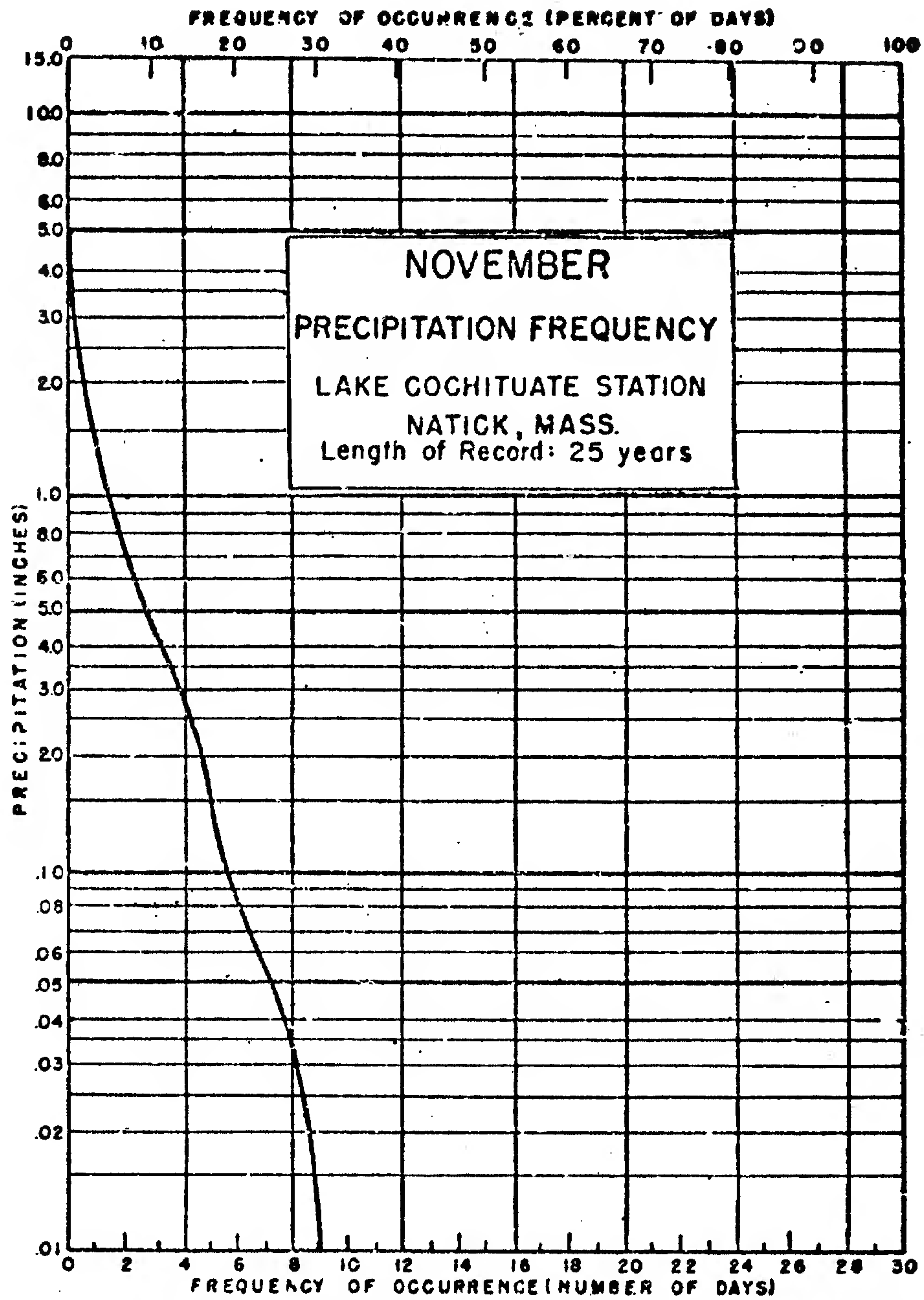
Figure 41



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.26 inches or more precipitation may be expected to occur 3.0 days during October (or approximately 16 percent of the days).

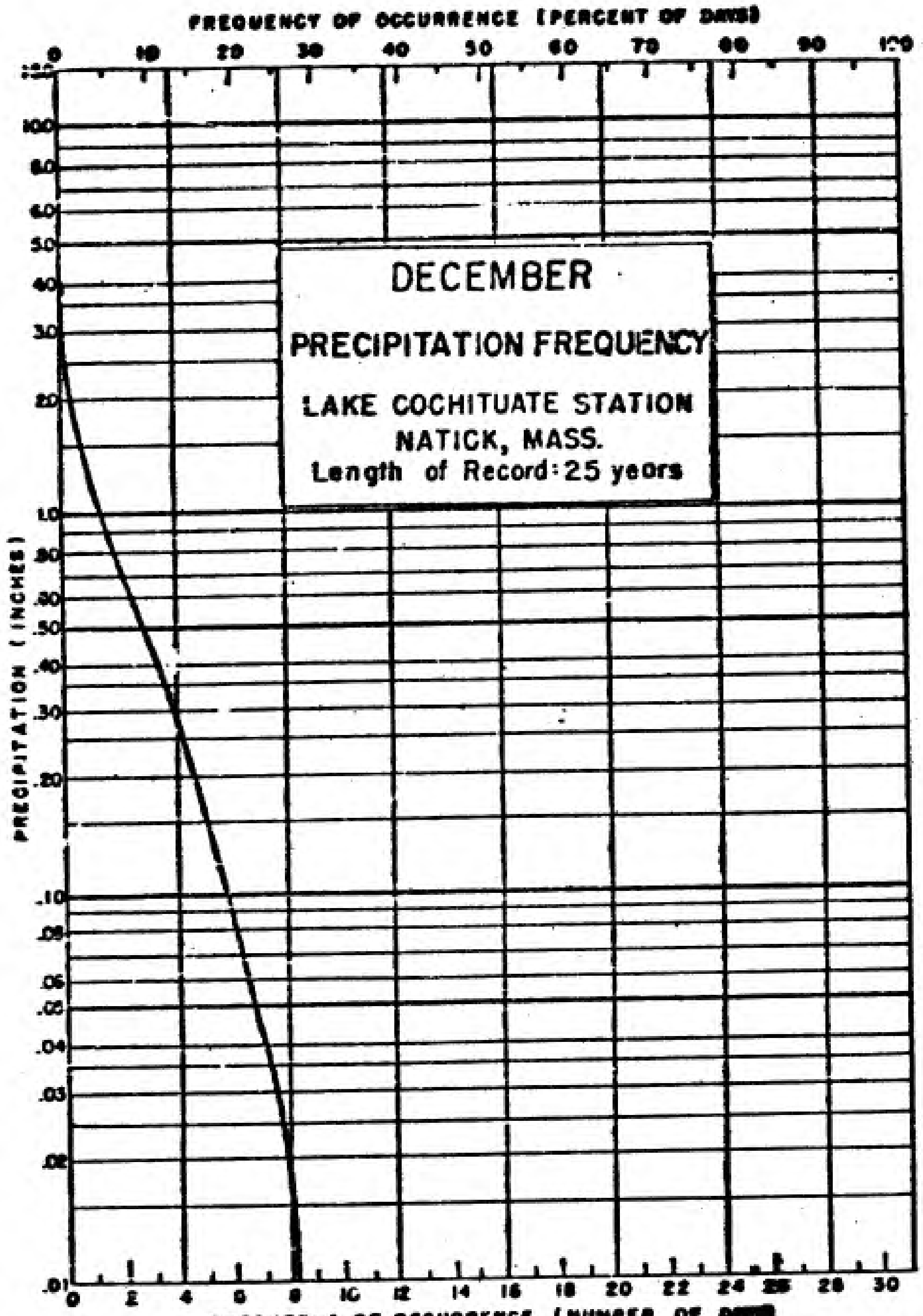
Figure 12



Numbe. of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.11 inches or more precipitation may be expected to occur 5.5 days during November (or approximately 18 percent of the days).

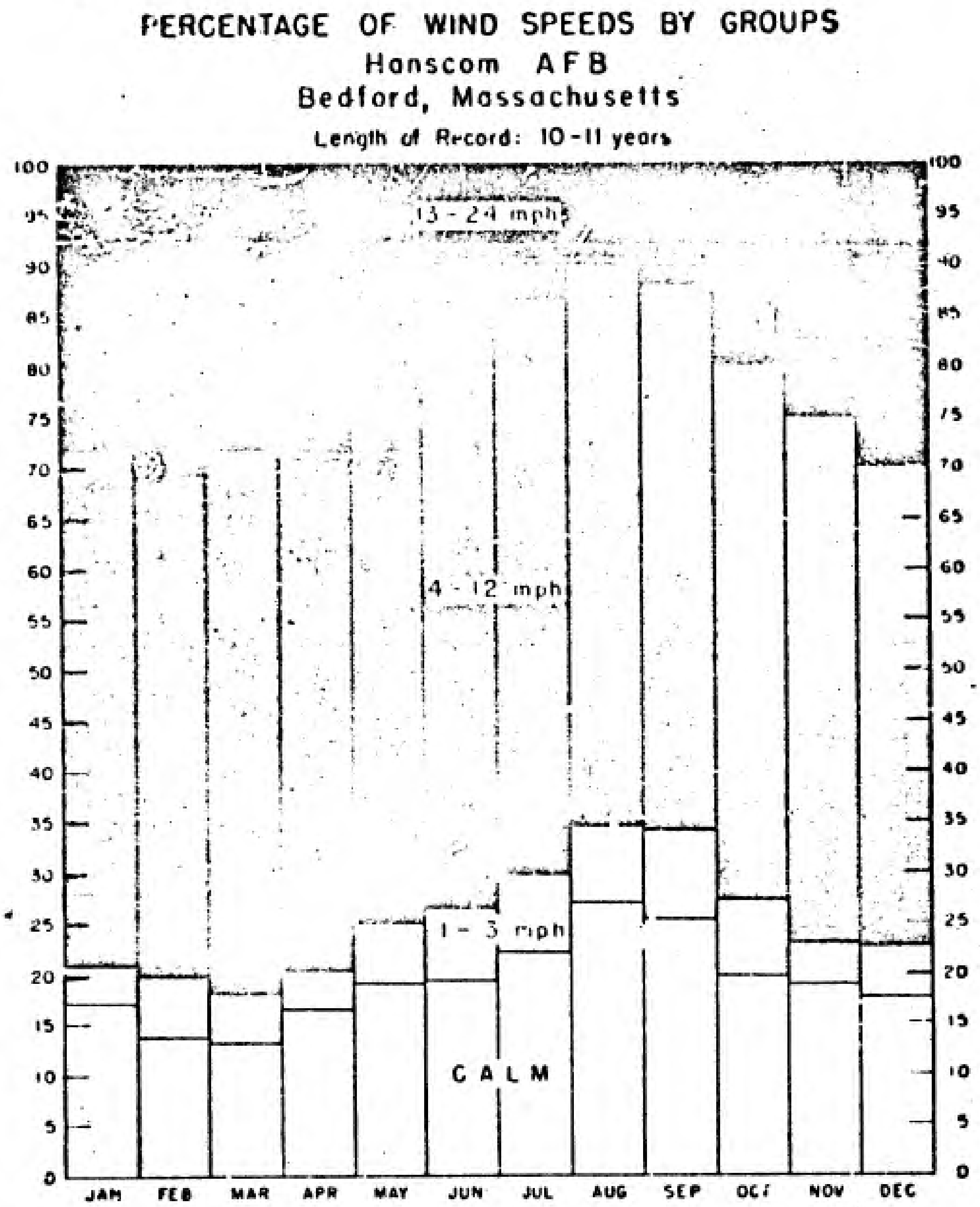
Figure 43



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.11 inches or more precipitation may be expected to occur 5.6 days during December (or approximately 18 percent of the days).

Figure 44



PERCENTAGE OF WIND SPEEDS BY GROUPS
Hanscom AFB
Bedford, Massachusetts
Length of Record: 10-11 years
13 - 24 mph
4 - 12 mph
1 - 3 mph
CALM
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Figure 45

TABLE V: FREQUENCY OF OCCURRENCE OF WIND SPEEDS
(Percent of observations)
Hanscom AFB
Bedford, Mass.

Period of Record: Feb. 1943 - Sept. 1953

Speed (mph)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Calm	17.2	13.9	13.3	16.7	19.1	19.5	22.3	27.1	25.5	19.9	19.0	17.6
1-3	3.8	6.0	4.9	3.8	6.0	7.1	7.5	7.6	8.8	7.5	4.0	5.3
4-12	50.8	49.5	53.7	50.7	53.0	55.2	57.2	55.7	54.0	52.9	52.2	47.5
13-24	25.1	25.8	25.0	24.9	20.8	17.7	12.9	9.5	11.[illegible]	18.4	22.5	25.3
25-31	2.5	4.0	2.7	3.5	1.1	0.5	0.1	0.1	0.3	1.3	1.9	3.6
32-46	0.5	0.8	0.5	0.4	0.1	0.0	0.0	0.0	0.0	0.1	0.5	0.7

TABLE VI: FREQUENCY OF OCCURRENCE OF WIND DIRECTIONS
(Percent of observations)
Hanscom AFB
Bedford, Mass.

Period of Record: Feb. 1943 - Sept. 1953

Direction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	5.8	5.9	5.0	3.5	2.5	2.4	2.2	2.9	4.2	4.3	5.0	4.8
NNE	5.4	4.5	5.0	3.6	3.2	2.7	2.6	3.4	3.0	3.9	3.7	3.7
NE	4.3	3.7	4.1	3.3	4.4	3.0	2.4	3.3	4.2	5.3	4.2	3.0
ENE	2.0	2.1	4.2	3.7	5.0	3.0	1.7	3.2	3.0	3.6	2.7	1.1
E	1.3	1.6	3.0	3.1	4.6	2.8	2.0	2.6	2.4	2.1	2.3	1.0
ESE	1.0	1.3	2.5	3.5	4.6	3.0	2.9	2.7	2.5	1.8	1.8	1.2
SE	1.2	2.0	2.4	3.4	4.1	3.0	2.6	2.3	2.3	2.4	1.6	1.1
SSE	1.9	2.7	2.8	2.5	3.4	2.4	2.9	2.3	3.4	1.9	2.2	1.6
S	3.2	3.3	3.2	3.2	3.7	3.5	5.1	5.0	5.6	4.4	4.3	2.6
SSW	5.5	4.9	6.8	6.1	6.9	10.2	11.2	7.6	7.3	7.0	6.2	3.9
SW	6.8	6.9	8.0	8.1	7.5	11.5	12.4	9.9	9.0	11.3	6.9	6.9
WSW	7.8	8.7	7.3	7.0	7.7	11.6	10.3	8.7	6.2	8.7	6.7	10.7
W	10.8	9.4	7.3	8.7	7.4	7.8	7.6	6.9	6.8	8.4	10.0	12.7
WNW	9.3	11.4	8.4	9.4	6.2	5.6	5.8	4.5	4.7	4.9	7.9	10.3
NW	9.4	10.9	7.6	7.6	5.2	3.8	3.0	3.8	5.2	5.8	9.3	10.8
NNW	7.2	7.0	9.2	6.6	4.4	4.0	3.1	3.9	4.8	4.3	6.4	7.0
Calm	17.2	13.9	13.3	16.7	19.1	19.5	22.3	27.1	25.5	19.9	19.0	17.6
Total obsv.	7,402	7,042	8,133	7,918	8,179	7,918	8,178	8,181	7,909	7,430	7,180	7,437

TABLE VII: FREQUENCY OF OCCURRENCE OF WIND SPEEDS BY DIRECTION
Hanscom AFB
Bedford, Mass.

Period of Record: Feb. 1943 - Sept. 1953

Direction	Percentage Frequency of Occurrence 1-3 mph	4-12 mph	13-24 mph	25-31 mph	32-46 mph	Total No. of Observations %	Obs.	Mean Wind Speed (mph)
N	0.3	2.8	0.9	0.1	0.0	4.0	3,718	8.6
NNE	0.3	2.7	0.7	0.0	0.0	3.7	3,443	9.1
NE	0.4	2.6	0.7	0.0	0.0	3.7	3,482	8.7
ENE	0.3	2.2	0.5	0.0	0.0	3.0	2,753	8.7
E	0.3	1.8	0.3	0.0	0.0	2.4	2,255	8.1
ESE	0.2	1.8	0.4	0.0	0.0	2.5	2,278	8.6
SE	0.2	1.9	0.3	0.0	0.0	2.4	2,225	7.9
SSE	0.3	1.9	0.3	0.0	0.0	2.5	2,326	8.0
S	0.5	3.0	0.5	0.0	0.0	3.9	3,632	7.7
SSW	0.5	4.9	1.5	0.1	0.0	7.0	6,526	9.5
SW	0.5	5.9	2.2	0.1	0.0	8.8	8,198	10.1
WSW	0.5	5.4	2.4	0.2	0.0	8.5	7,852	10.5
W	0.6	5.5	2.1	0.3	0.0	8.6	7,979	10.4
WNW	0.4	3.8	2.7	0.4	0.1	7.3	6,791	12.5
NW	0.4	3.6	2.4	0.4	0.1	6.8	6,283	12.6
NNW	0.3	3.0	2.0	0.2	0.0	5.6	5,208	12.0
Calm						19.3	17,958	

TYPES OF SKY CONDITIONS
Hanscom AFB
Bedford, Massachusetts

Length of Record: 5 years

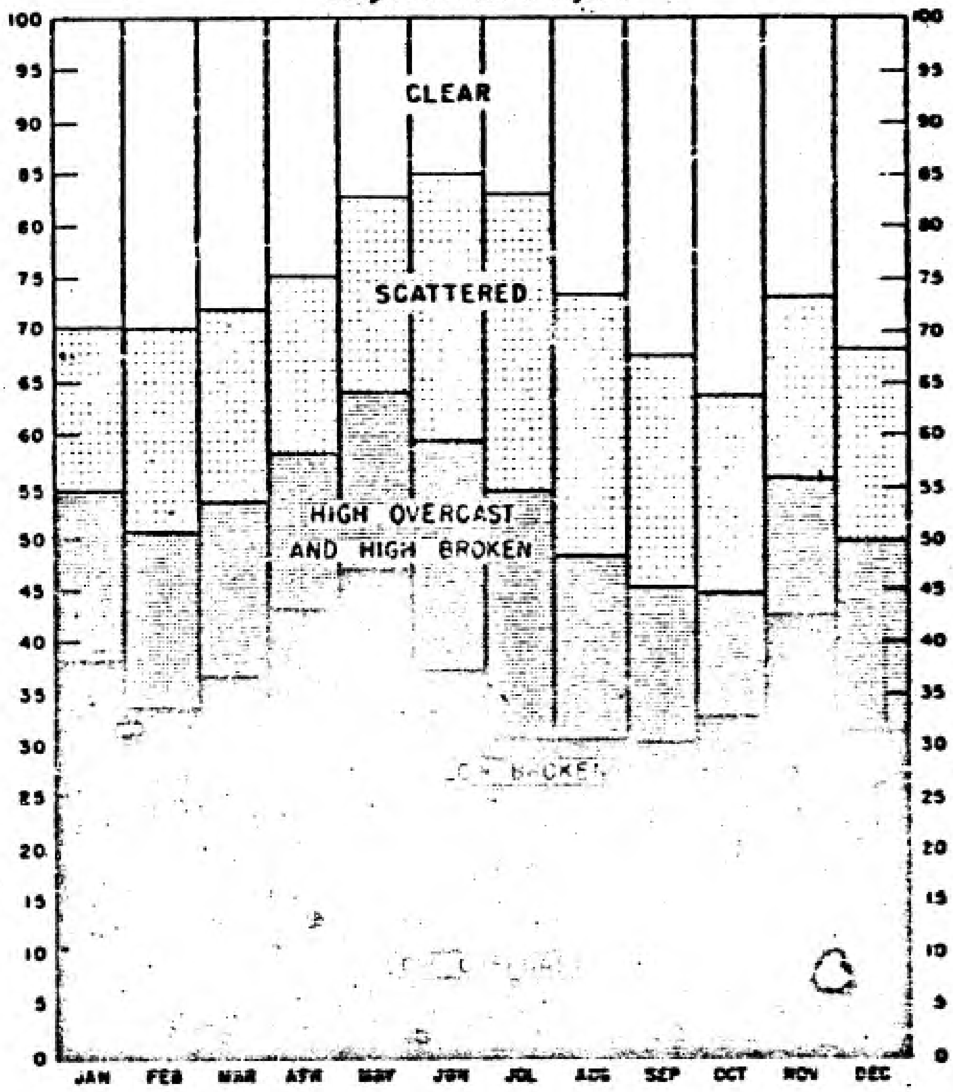


Figure 16

TABLE VIII: VISIBILITY AND SKY CONDITIONS
(Percent of Observations)
Hanscom AFB
Bedford, Mass.

Length of Record: 6 - 11 Years

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Obstructions to vision												
Fog	4.6	2.9	3.5	2.7	4.9	2.9	3.1	3.3	4.8	6.3	3.8	2.2
Smoke and/or haze	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.3	0.1
Blowing snow and/or dust	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Precipitation	2.8	2.5	1.2	0.2	0.1	0.1	0.1	0.2	0.3	0.1	0.7	1.8
Total obs. ≤ 1 mile	7.5	5.8	4.3	2.9	5.1	3.0	3.2	3.7	5.1	6.5	4.9	4.2
Visibility (miles)												
0 - 1/8	1.6	1.0	1.2	0.7	1.3	0.8	0.8	1.3	1.8	2.3	1.2	1.0
3/16 - 1/4	1.2	1.0	0.7	0.2	0.8	0.5	0.6	0.5	0.7	1.1	0.7	0.7
5/16 - 1/2	2.7	1.7	1.4	0.7	1.5	1.1	1.1	1.2	1.3	1.8	1.7	1.3
5/8 - 3/4	2.1	2.2	1.6	1.3	1.4	0.6	0.7	0.7	1.2	1.3	1.3	1.2
1 - 2 1/4	8.6	8.3	8.4	6.7	9.0	7.1	7.4	9.4	8.1	8.3	9.1	6.5
2 1/2	0.9	1.3	1.2	0.7	0.9	0.5	0.8	1.4	0.9	0.9	0.9	1.0
3 - 6	19.3	17.8	16.8	16.8	21.4	20.8	23.6	31.1	25.9	21.9	18.8	21.3
7 - 9	12.2	10.4	10.8	9.6	11.5	12.2	14.4	11.5	12.9	13.6	13.5	11.4
10 and over	51.5	56.4	57.9	63.3	52.1	56.4	50.6	43.0	47.1	48.8	52.7	55.6
Sky condition*												
Clear	29.7	29.8	28.1	25.0	17.1	14.9	16.7	26.5	32.4	36.1	26.7	31.9
Scattered	15.6	19.6	18.5	17.0	18.9	25.7	28.7	25.1	22.2	19.1	17.5	18.5
High broken or high overcast**	16.6	16.9	16.8	14.9	17.1	22.0	23.7	17.5	14.9	11.8	13.3	18.3
Low broken	5.1	6.9	8.7	12.4	11.6	13.7	12.7	13.8	9.2	9.8	8.9	6.7
Low overcast	32.0	26.8	28.0	30.8	35.3	23.7	18.2	17.1	21.3	23.1	33.6	24.6

*Low clouds are those below 10,000 feet. High clouds are those at or above 10,000 feet
**With scattered or no low clouds

TABLE IX: FREQUENCY OF OCCURRENCE OF CEILING HEIGHTS
(Percent of Observations)
Hanscom AFB
Bedford, Mass.

Period of Record: Feb. 1943 - Sep. 1953

Frequency of Occurrence

Month	0 to 400 ft.	500 to 900 ft.	1000 to 2000 ft.	2100 to 3000 ft.	3100 to 5000 ft.	5500 to 9500 ft.	Unlimited	Total No. Obs.
Jan	6.9	7.5	8.8	5.7	7.3	7.1	56.6	7,410
Feb	4.5	7.6	8.0	5.9	6.5	6.5	61.0	7,046
Mar	4.9	6.5	9.1	5.4	8.2	7.4	58.5	8,139
Apr	3.3	6.5	8.2	4.8	10.8	10.8	55.6	7,920
May	6.3	8.8	8.3	4.5	7.7	9.4	55.0	8,183
Jun	3.5	5.3	5.7	3.1	7.2	8.2	66.9	7,920
Jul	2.8	5.1	6.4	2.9	5.3	5.8	71.7	8,178
Aug	3.3	5.1	7.0	3.6	6.3	5.8	68.9	8,183
Sep	4.6	5.0	7.3	3.9	5.8	5.0	68.5	7,913
Oct	5.9	5.6	5.9	3.4	6.3	5.4	67.5	7,433
Nov	5.3	6.6	9.8	4.9	7.8	7.9	57.7	7,195
Dec	3.9	5.1	7.4	5.2	6.5	6.9	65.0	7,440

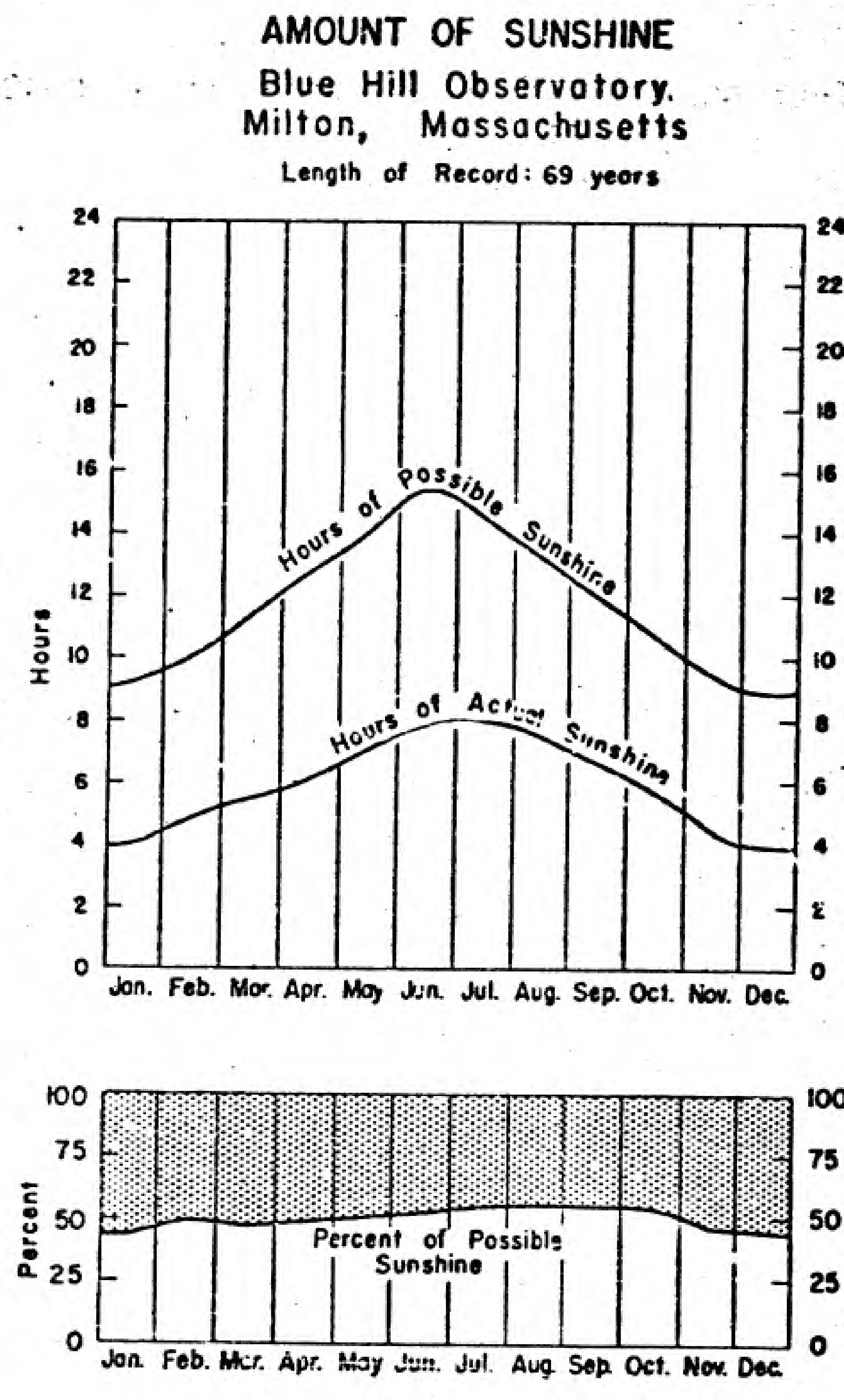

AMOUNT OF SUNSHINE
Blue Hill Observatory.
Milton, Massachusetts
Length of Record: 69 years
Hours
24
22
20
18
16
14
12
10
8
6
4
2
0
Hours of Possible Sunshine
Hours of Actual Sunshine
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
Percent
100
75
50
25
0
Percent of Possible Sunshine
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.

Figure 47

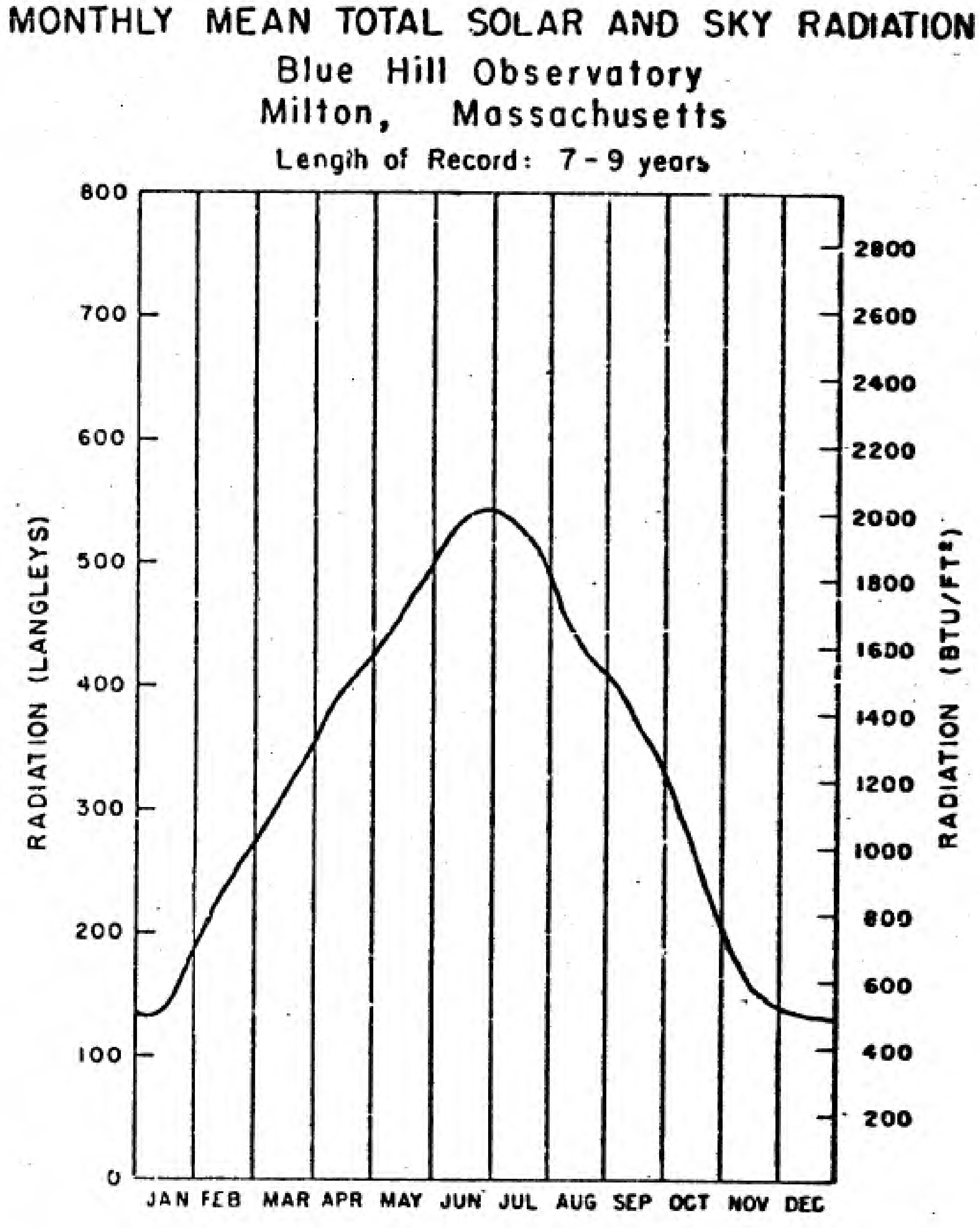
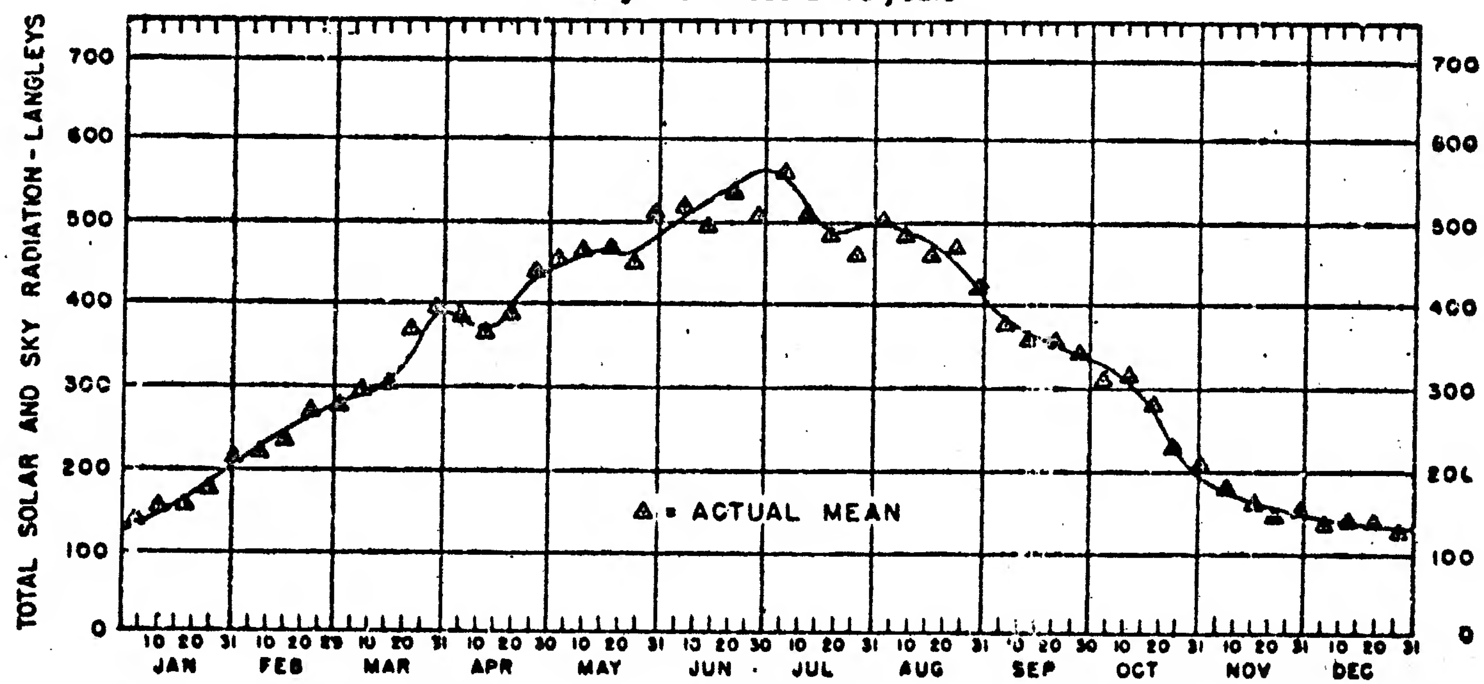

MONTHLY MEAN TOTAL SOLAR AND SKY RADIATION
Blue Hill Observatory
Milton, Massachusetts
Length of Record: 7 - 9 years
RADIATION (LANGLEYS)
RADIATION (BTU/FT²)
800
700
600
500
400
300
200
100
0
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Figure 48

WEEKLY MEAN VALUES OF DAILY TOTAL SOLAR AND SKY RADIATION
Blue Hill Observatory
Milton, Massachusetts
Length of Record: 15 years



Taken from I.F. Hand, Technical Paper No.11, U.S. Department of Commerce, 1949, p.8

Figure 49

TABLE X: MEAN MONTHLY MAXIMUM AND MINIMUM RELATIVE HUMIDITY (in %)*

Quartermaster Research & Engineering Center
Natick, Massachusetts

(Period of Record: Feb. 1956 - Jan. 1957)

Month	Mean Maximum	Mean Minimum
January	91.2	46.6
February	74.4	48.2
March	78.4	46.5
April	76.1	46.2
May	76.7	40.0
June	76.2	47.1
July	78.4	50.6
August	78.5	46.3
September	86.3	53.6
October	97.1	42.7
November	90.4	47.5
December	96.1	57.9

*Data for the months of February through September were obtained from hourly observations taken from 0730 to 1930 each day. During these months it is probable that daily maximum values occurred earlier than 0730 and as a result mean monthly values are too low. This also explains the higher values for October through January, when twenty-four hourly observations were taken.

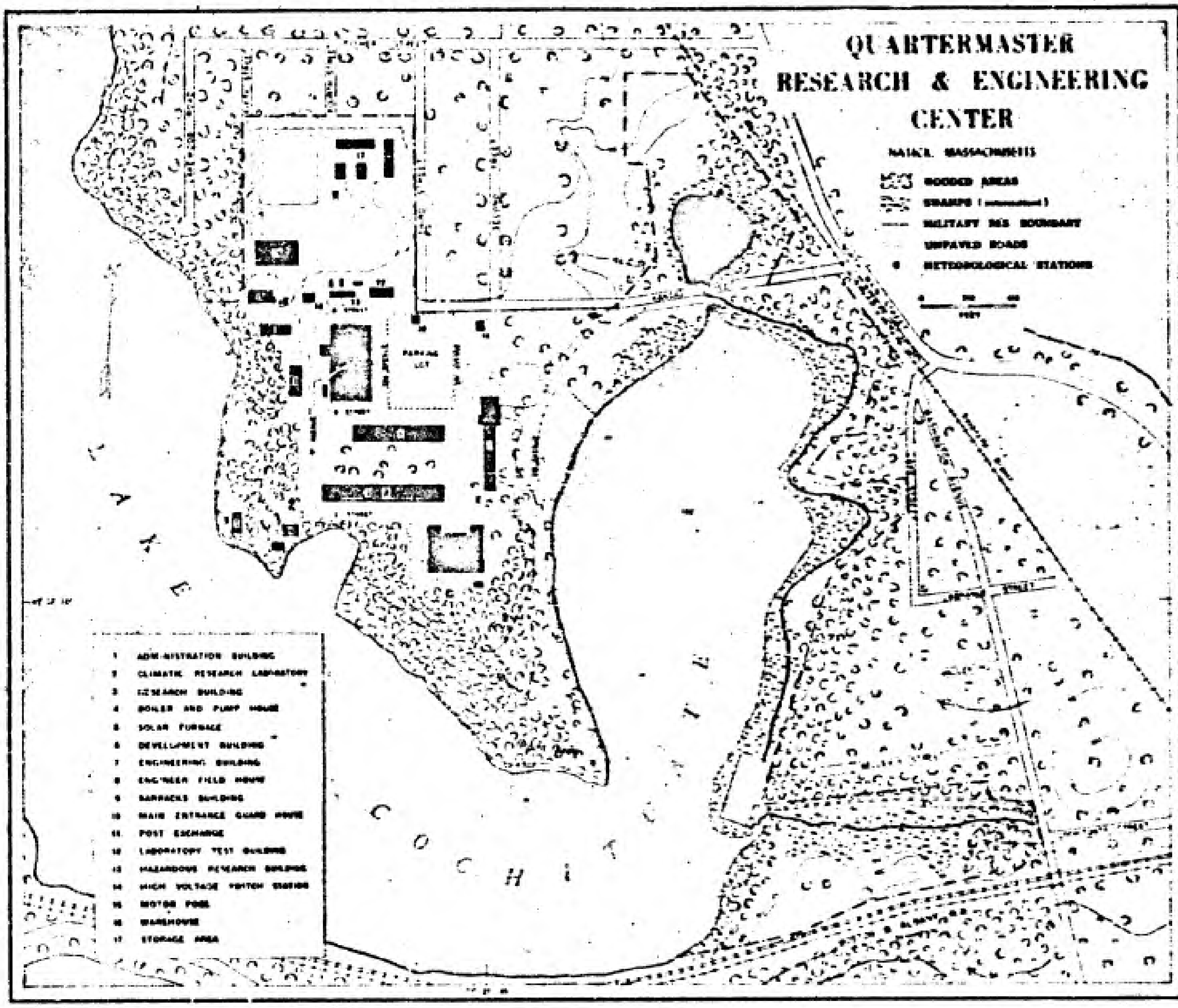

QUARTERMASTER
RESEARCH & ENGINEERING
CENTER
NATICK, MASSACHUSETTS
WOODED AREAS
MILITARY RES BOUNDARY
UNPAVED ROADS
METEOROLOGICAL STATIONS
PARKING LOT
1 ADMINISTRATION BUILDING
2 CLIMATIC RESEARCH LABORATORY
3 RESEARCH BUILDING
4 BOILER AND PUMP HOUSE
5 SOLAR FURNACE
6 DEVELOPMENT BUILDING
7 ENGINEERING BUILDING
8 ENGINEER FIELD HOUSE
9 BARRACKS BUILDING
10 MAIN ENTRANCE GUARD HOUSE
11 POST EXCHANGE
12 LABORATORY TEST BUILDING
13 HAZARDOUS RESEARCH BUILDING
14 HIGH VOLTAGE SWITCH STATION
15 MOTOR POOL
16 WAREHOUSE
17 STORAGE AREA
LAKE COCHITUATE

Figure 50

DISTRIBUTION LIST

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Washington 25, D. C.

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Department of the Army
Temp. Bldg. T-7, Gravelly Point
Washington 25, D. C.
Attn: Research & Dev. Div.

1 CO, Chemical Corps
Chem. Radiological Labs.
Army Chemical Center, Maryland
Attn: Technical Library

1 Chief Chemical Officer
Department of the Army
Bldg. T-7, Gravelly Point
Washington 25, D. C.
Attn: Res. & Dev. Div.

2 The Surgeon General
Department of the Army
Main Navy Bldg., Wash. 25, D. C.
(1-R&D Div., 1-Tech Liaison Off)

1 The Armed Forces Medical Library
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2 CO, Hq., Medical Nutrition Lab.
Fitzsimons Army Hospital
Denver, Colorado
(1-Dr. Friedemann)

1 Armed Forces Institute of Pathology
Washington 25, D. C.

1 Chief, Armed Services Medical Procurement Agency
84 Sands St., Brooklyn 1, N.Y.
Attn: Property Officer
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1 Chief of Transportation
Department of the Army
Temp Bldg. T-7, Gravelly Point
Washington 25, D. C.

2 Commanding Officer
Transportation Res & Dev Command
Ft. Eustis, Va.

CONTINENTAL ARMY COMMAND

1 C.G., U.S. Continental Army Command
Ft. Monroe, Va.

1 President, CONARC Board No. 1
Ft. Sill, Okla.

1 President, CONARC Board No. 2
Ft. Knox, Ky.

1 President, CONARC Board No. 3
Ft. Benning, Ga.

1 President, CONARC Board No. 4
Ft. Bliss, Texas

1 President, CONARC Board No. 5
Ft. Bragg, N. C.

1 President, CONARC Board No. 6
Camp Rucker, Alabama

AIR FORCE

2 Department of Air Force
Hqs., USAF, Wash 25, D. C.
(1 DC/S Material, 1 DC/S Dev.)

1 Commander
Air University
Maxwell AFB, Alabama

1 Commandant
USAF School of Aviation Medicine
Randolph AF Base
Randolph Field, Texas

1 Commander, Arctic Aeromedical Lab.
APO 731, Seattle, Washington

1 Commander
Air Res & Dev Command, P.O. Box 1395
Baltimore, Maryland

1 Commander
Wright Air Development Center
Wright Patterson AF Base, Ohio
Attn: Tech Library

1 Commander
Strategic Air Command
Offutt AF Base, Nebraska

1 Chief, Nutrition Br.
Air Development Center
Aero-Medical Lab.
Wright Patterson AFB, Ohio
Attn: Dr. Harry C. Dyme

1 Commander
AF Cambridge Research Center
Air Research & Development Cmd.
Laurence G. Hanscom Field
Bedford, Mass.
Attn: CRTOTT-2

NAVY

1 Director
Naval Research Laboratory
4th & Chesapeake St., S. W.
Washington 25, D. C.

1 Chief, Bureau of Ordnance
Department of the Navy
Washington 25, D. C.
Attn: R&D Div.

1 Naval Medical Research Institute
National Naval Med. Res. Center
Bethesda, Md.

2 Chief of Naval Research
Washington 25, D. C.
Attn: Code [illegible]

1 Chief, Bureau of Ships
Department of the Navy
Washington 25, D. C.
Attn: Code 338

1 Chief, Bureau of Med. & Surgery
Dept. of the Navy, Wash 25, D. C.
Attn: Code 33

1 Commander, U.S. Naval Ord. Test
Station, China Lake, Calif.
Attn: Code 753

1 Chief, Bureau of Aeronautics
Dept of the Navy, Wash 25, D. C.
Attn: Code AE 52

1 Chief, Bureau of Supplies & Accounts
Department of the Navy
Washington 25, D. C.

BOARDS & COMMITTEES

1 Army Committee on Environment
Chief, Research & Development
Pentagon, Washington, D. C.

1 Army Comm. on Insect and Rodent Control
Office, Deputy Chief of Staff for Logistics
Pentagon, Washington, D. C.

1 Army Research Committee
Chief, Research & Development
Pentagon, Washington, D. C.

MISCELLANEOUS

1 The Army Library
Pentagon Bldg., Washington 25, D. C.

1 Commandant, National War College
Ft. McNair, Washington 25, D. C.

1 Commandant, Command & General Staff School
Ft. Leavenworth, Kansas

1 Superintendent, U.S. Military Academy
West Point, New York

1 National Research Council
2101 Constitution Ave., Washington, D. C.
Attn: Advisory Bd. on QM R&D

5 Armed Services Technical Information Agency
Document Service Center
Knott Building, Dayton 2, Ohio
Attn: DSC-SD

1 Commanding Officer, Detroit Arsenal
28251 Van Dyke St., Centerline, Mich.
Attn: Res & Engr. Div.

1 U. S. Department of Commerce
Weather Bureau Library, Washington, D. C.

1 Commanding Officer
Hqs., Mountain and Cold Weather Training Command
Fort Carson, Colorado

1 Central Intelligence Agency
Collection & Dissemination
2430 E St., N. W.
Washington 25, D. C.

1 Marine Corps Equipment Board
Marine Development Center
Marine Corps School
Quantico, Va.

1 Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.
Attn: Tech Rpts Sec [illegible]

1 U. S. Department of Agriculture Library
Washington 25, D. C.

1 Commandant
Industrial College of the Armed Forces
Ft. McNair, Washington 25, D. C.